Petrol Models

2/-

MP LTD

PETROL MODELS

by

R. H. WARRING

MODEL PUBLICATIONS, LTD.
MITCHAM · SURREY
1945

CHAPTER I

GENERAL

THE petrol driven model aeroplane is an attractive proposition to any air-minded person and represents the nearest approach possible to the thrills and technique of full-sized flying. The general term "petrol model" covers a variety of types and sizes of model aircraft powered by miniature aero-motors. These models may have a wingspan of only 40 ins.—or even less on control line types—with an aero-motor of about 1·5 c.c. capacity, ranging to very large models of 14 or 15 ft. span carrying radio control equipment. The majority of models are from 4 to 7 ft. span, with corresponding aero-motor sizes of 3 to 10 c.c.

The greatest developments in petrol model flying have taken place in America, which country has specialised in the production of miniature aero-motors and petrol model kits and accessories for a number of years. But of the pioneers of the movement we must mention Colonel C. E. Bowden of this country, who started building and flying petrol models soon after the last war, held the first petrol model records and is still an active and leading authority on the subject.

The British petrol model movement received a severe setback in 1940 when the flying of this type of model was banned by the Air Ministry, owing to the state of emergency then existing. In May, 1944, these regulations were relaxed and flying could be resumed in areas north of a line between Southwold, Bury St. Edmunds, Bedford, Gloucester and the Bristol Channel, subject to certain conditions. More recently Air Ministry Regulations have permitted the resumption of petrol flying all over the country.*

The American petrol model movement has continued right through the war and, although severely handicapped by shortage of materials and the cessation of the production of miniature aero-motors for "the duration" some remarkable advances have taken place. Most noteworthy is the development of control line flying, an entirely new phase of the aeromodelling hobby which has rivalled free flying models in popularity. Full details of this are given in a companion volume to this booklet—*Control Line Flying*—produced by the same publishers. Even before the war the quality and performance of British petrol models was generally admitted to be inferior to those of our American friends, and with the gap of four years occasioned by the ban we have a considerable leeway to make up.

The object of this booklet is to review the present state of knowledge of the petrol model, to acquaint the confirmed enthusiast with the latest design and construction method and present the newcomer to the hobby with a sound groundwork knowledge of the subject and the best methods of tackling the various problems as they arise.

*See Appendix.

The petrol model can be considered as two separate items. First there is the model itself which, being generally quite large, is more costly and takes longer to build than the popular rubber-driven or glider model; and secondly there is the aero-motor, which is again quite costly and easily damaged if mishandled. Since these models are larger and heavier than the popular duration types with which most people first start their aeromodelling activities the consequences of a crash are usually more serious—not only to the machine and motor, but also to property should the model fly away and "land" in a built-up area.

Before attempting to build and fly a petrol model the enthusiast should have had some previous experience of model flying, so that he has at least a rudimentary knowledge of the principles of flight; some of the problems of balance and trim, and the behaviour of a model aeroplane in free flight. Experience, backed by sound knowledge, is the keynote of successful flying and the avoidance of those often disheartening crashes resulting from over-optimism or the desire to do things quickly.

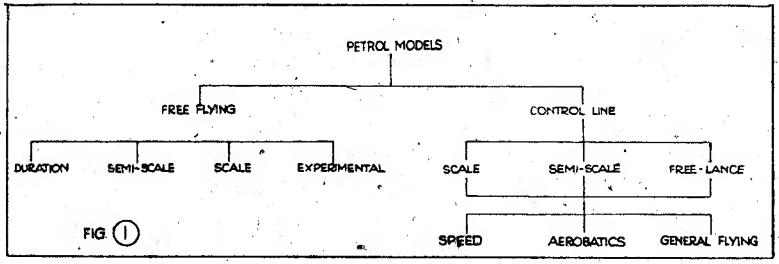


FIG. 1

There are two main classes of petrol models:—(i) free flying models and (ii) control line models, of which only the former concern us here Free flying petrol models generally fall into one of four types, viz.:—

(a) *Duration models*, or models designed for sheer performance.

(b) *Semi-scale models* which bear a resemblance to full-sized aircraft, but incorporate many features of type (a) to avoid the disadvantages of the true outline scale model.

(c) *Outline scale models*, or replicas of full-sized aircraft to a definite scale.

(d) *Experimental models*, which include all such unorthodox types as pterodactyls, rotaplanes, canards, etc., etc.

Models of type (a) incorporate the features of the normal rubber driven model, namely, good stability, good performance and reasonable freedom from crashes. To the layman or the beginner the outline scale model is the most attractive, but both performance and stability suffer from the fact that a full-sized prototype is designed to be *controlled by a pilot*, whereas in a model the "control" or stability factor must be inherent in the *design*. In trying to effect a compromise in models of this type usually the outline shape must be distorted or changed from true

scale to some extent or the inherent stability of the model is insufficient. The great secret of all successful flying is a stable model and beginners especially should choose a model of type (a) for their first attempt.

The fact that model requirements are somewhat different from full-sized conditions has resulted in high-performance models of type (a) being developed which have little or no resemblance to a full-sized aeroplane. This has led the uninitiated to call them "freaks," when in fact they are high-performance *aeroplanes*, in the true sense, *specifically designed under model conditions*.

However, there are many aeromodellers with a definite full-size complex, and to them a model aeroplane *must* look something like a full-sized aeroplane, irrespective of whether this is good design practice or not. This has led to the semi-scale model of type (b) which does look like a full-sized aeroplane, generally incorporating a cabin and other full-sized features, but is designed on duration lines with ample stability. The performance of a well-designed model of this type compares very favourably with that of models in type (a).

It is the writer's own opinion that free flying petrol models should be either of type (a) or type (b), and the experimental types of class (d). leaving true outline flying scale petrol models for control line work where the instability factor inherent in such types is no handicap. Of course, there are some full-sized designs which will fly reasonably well when scaled down to model sizes, and a great part of the secret of any free flying scale model is a good choice of prototype in the first instance.

Experimental models are a class unto themselves and beyond the scope of this booklet. The petrol-driven model aeroplane does, however, present an excellent medium for experiment, and many full-sized aircraft designs have first been tried out in this form. The Germans in particular have done much work on these lines, also the Americans in connection with pterodactyl or tailless aeroplanes.

The flying scale model is also a specialist undertaking, although the general design principles of the duration and semi-scale types and many of the structural features apply.

CHAPTER II

DESIGN PRINCIPLES

THE chief requirement of the free-flying petrol model is that it should have an ample reserve of stability under all conditions; that it should fly on an even keel both under power and on the glide and return quickly to this equilibrium position if upset by any disturbing force, such as a gust of wind. Structurally it must be strong enough to absorb quite heavy landing shocks, which may not always be made on the undercarriage, for it may "land" in a tree, or a ploughed field, as well as taking normal handling loads such as sustained during launching, assembling, etc. Flight loads may be considered relatively unimportant, for if the aeroplane is stressed to stand up to normal model usage it will be more than strong enough to take any loads likely to be sustained during flight.

Aerodynamic and structural design may be considered separately, the main requirements of the first being ample stability with high efficiency, and of the second ample strength with light weight.

The principal features governing the stability of a model aeroplane are:—

(i) Location of the centre of pressure (i.e., centre of lift).
(ii) Location of the centre of gravity.
(iii) Position of the thrust line.
(iv) Location of the centre of resistance of the whole model.
(v) Location of the centre of lateral area (C.L.A.), i.e., the centre of all the side areas.

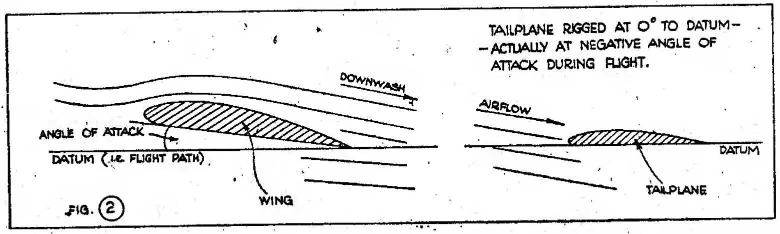
Each factor is related to the others and each must be in correct proportion to the others.

Happily, there is considerable latitude permissible in most designs, although as a general rule the faster the model flies, i.e., the more powerful the motor fitted, the more marked any tendency towards instability becomes. General design rules applying to all types of models can be laid down for factors (i) to (iv) above and any adjustments necessary can be made first during rigging before flying and then during the actual test flying. Correct location of the C.L.A.—factor (v)—is simply a matter of designing the right size and right *shape* of fin for the particular model and is a design feature which must be fixed before the model is built, and hence of considerable importance.

Fore-and-aft location of Centre of Pressure

Basically there are two methods of rigging an aeroplane for flight :—

(i) With the wings contributing all the lift.
(ii) With the tailplane carrying part of the load.



In case (i) the wing is rigged at an efficient angle of incidence and the tailplane set at that angle of incidence which corresponds to the angle of attack for zero lift when in flight. To clarify this point it must be understood that the airflow over a model is deflected downwards after passing over the wings, and if the tailplane was rigged parallel to the flight path or datum, i.e., at zero *incidence*, the angle of *attack* of the tailplane, i.e., the angle at which the airflow meets the tailplane in flight, would be some small negative angle—see Fig. 2. This downwash angle is approximately equal to one half the incidence of the wings and must always be allowed for when rigging the tailplane. Even if the wings and tailplane are not in a direct line, i.e., the tailplane is well above, or below, the wings, downwash effect is still appreciable. A more accurate formula giving the downwash angle at any point behind the wings is:—

$$\epsilon = \frac{55\cdot7C_L}{A.R.} \times (x+1)^{-.38} \times (y+1)^{-.23}$$

where ϵ=downwash angle.
x=height above, or below, wing, expressed in chord lengths.
y=horizontal distance from wing trailing edge, expressed in chord lengths.

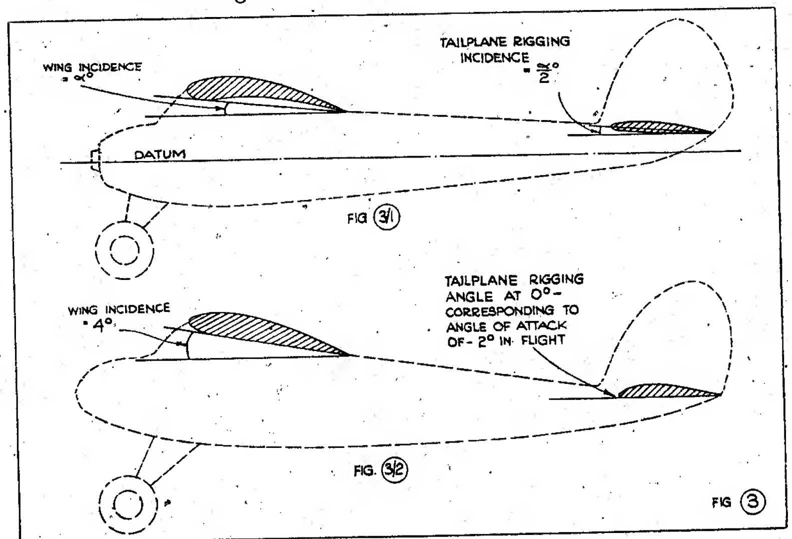


FIG 3

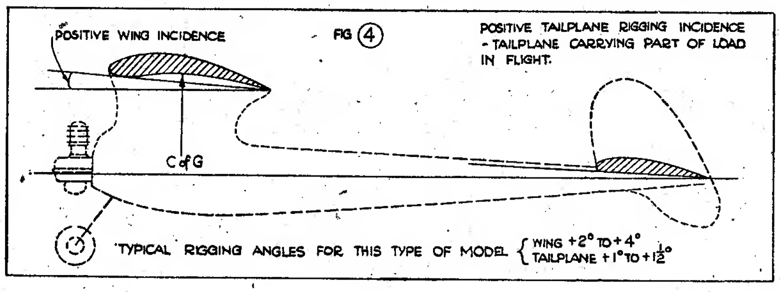
This is rather cumbersome to use and the simple approximation of one-half the wing incidence is more convenient for the average designer. The correct tailplane rigging angle can also be found by test-gliding as detailed in a later chapter.

Thus with a symmetrical or so-called "non-lifting" tailplane the tailplane rigging angle will be a small positive angle, equal to one half the wing incidence—Fig. 3/1. With a "lifting section" tailplane incidence is adjusted until the angle of attack equals that for zero lift for that particular section. Most "lifting section" model tailplanes employ a thin modified Clark Y or similar aerofoil section when the angle of attack for zero lift of that section is about —2 degrees—Fig. 3/2.

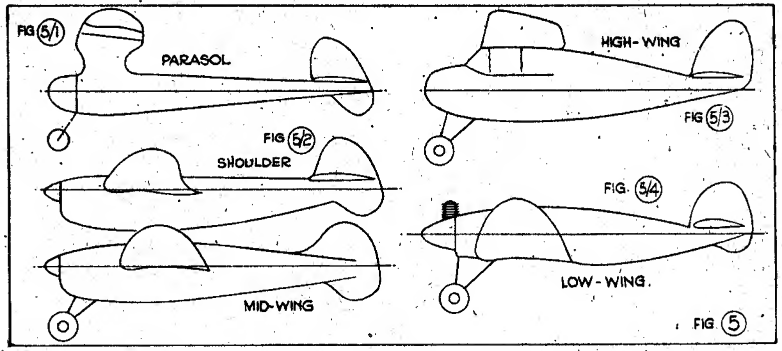
Since in both these cases the wings are the sole contributors to the lift the centre of gravity is placed directly under the centre of pressure of the wings, which is about 35 per cent. of the average chord back from the leading edge at the flight angles of most normal models. Actually this position is also dependent upon the location of the centre of resistance and height of C.P. above the C.G., but the calculations involving this factor are lengthy and rather tedious. Any adjustment necessary is best found during the initial flight tests.

With the tailplane rigged at some lifting angle, and thus carrying part of the load, the C.G. position is moved farther aft. Actually by suitable adjustment of the rigging angles a C.G. position of anywhere between 40 and 100 per cent. of the average chord can be obtained, or even beyond the trailing edge, but the farther aft the C.G. the more critical adjustment becomes.

For best longitudinal stability there should be between three and five degrees between the angle of *attack* of the wings and the angle of *attack* of the tailplane when in flight, the wings being at the greater (positive) angle. Considering this with the above it can be stated that the most stable arrangement is with the C.G. positioned under (or nearly under) the centre of pressure of the wings and the tailplane rigged at zero lift. This holds good for most semi-scale and duration types, although with the parasol wing arrangement of certain high-efficiency designs it is better to have the tail carrying part of the load.



Wing positioning has some considerable bearing on stability and rigging. The various positions are illustrated in Fig. 5. Duration types are almost invariably parasol or high-wing, although fully streamlined models may employ a shoulder or mid-wing. In general, the higher the wing the more stable the model, and in fact models with extreme parasol mountings have proved exceptionally stable, especially under high power, provided that the side areas are correctly proportioned. Beginners to the hobby should always gain experience with parasol or high wing types before attempting other designs.



The tailplane should definitely be rigged to carry part of the load on a parasol model. Authorities differ as to how far aft the C.G. can be located with safety, but the writer favours a position 50 per cent. of the average chord; never further aft than 66 per cent. of the average chord from the leading edge. Similar rigging may be adopted on high wing models, although the "non-lifting" tailplane is here less tricky, i.e., rigged as in 3/1 or 3/2.

Position of the thrust line

The position of the thrust line and the location of the centre of resistance will have considerable bearing on the difference between "engine-on" and "engine-off" flight. In the case of the parasol model—Fig. 6/1—where the centre of resistance is high and the thrust line low there is a considerable nose-up tendency during power flight which might well stall the model unless compensated. The same is present to some extent in most high wing models—6/2. Actually this is quite simply overcome by tilting the thrust line slightly downwards, i.e., adding downthrust, the amount required being easily found by practice. This nose-up tendency can, however, be used to advantage on models of type 6/1 by trimming for a tight circling climb. This type of climb is most spectacular—a rapid upward spiral—but there is always the danger of it developing into a spiral dive if the model is slightly out of adjustment, or the side areas are not correctly proportioned. The use of downthrust is safer for the beginner.

On a low wing model, Fig. 6/3, there may be a nose-down force

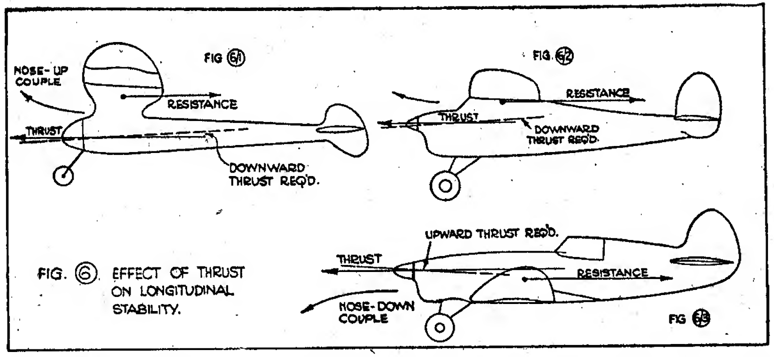


FIG. 6. EFFECT OF THRUST ON LONGITUDINAL STABILITY.

under power, which may make the model stall on the glide, or, if adjusted for glide, may cause a dive under power. Slight upthrust is indicated here to cure this fault.

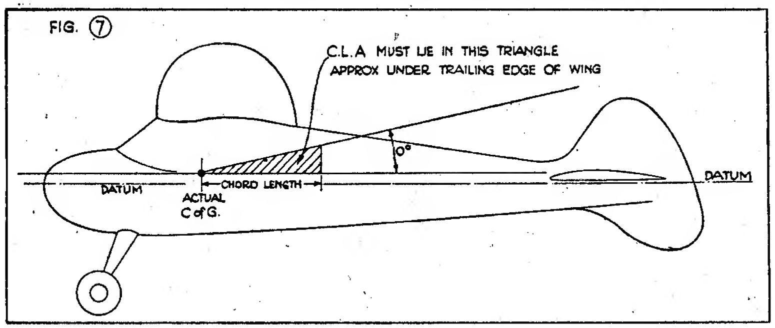
The ideal arrangement would be to get the line of action of the thrust and the centre of resistance co-incident, but this is not always possible, since it may mean sacrificing some other desirable characteristic, such as stability.

Centre of Lateral Area

One of the most important features in any design is the correct size and shape of fin required to give adequate directional, lateral and spiral stability under all conditions of flight. Good directional stability is ensured by a fin of between 7 and 10 per cent. of the wing area, the which size fin, together with adequate dihedral, also takes care of lateral stability. Spiral stability is given by correct placement of the centre of lateral area with respect to the C.G.

The C.L.A. should lie within an area bounded by a line parallel to the datum through the C.G. and another line through the C.G., making an angle of 10 degrees with it—see Fig. 7. The size (i.e., area) given above should then fix the exact position of the C.L.A. as about one half to one times the root chord of the wing behind the C.G. If this latter requirement is not met the fin area must be adjusted accordingly.

FIG. 7



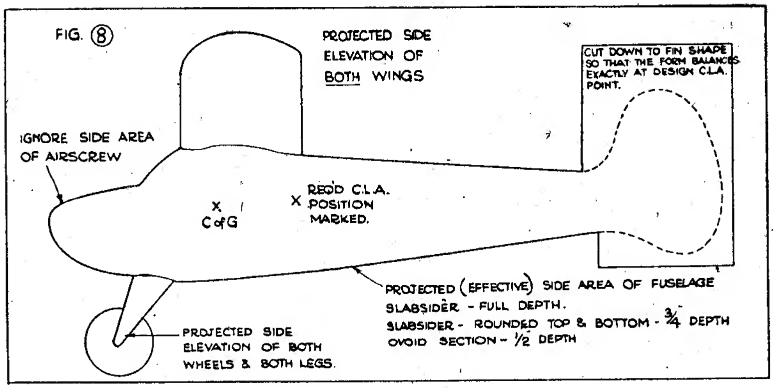


FIG. 8

The simplest method of finding the C.L.A. is to plot the side view of the whole model (or a scale reduction of the side elevation) on thick card of uniform texture, projecting the side area of both wings, etc., as in Fig. 8 ; cut out carefully, leaving plenty of surplus card around the fin, stick a pin through the design C.L.A. and trim down the fin shape until the card form will balance horizontally and vertically about the pin. The pin is then at the centre of area of the card form, i.e., the centre of side area of the model. Alternatively, this method or a modification of it may be used to find the C.L.A. of any design, i.e, by first cutting out a card form of the side elevation of the model and finding the centre of area of the form.

Concerning dihedral little need be said. Straight dihedral of type 9/1 is generally adequate for all medium powered models. A dihedral angle of 10-11 degrees is then sufficient. This should be increased slightly on low wing types, or where a more powerful motor is used.

Polyhedral of type 9/2 is better suited to high powered models and is about the only safe type to use if a steep spiralling climb is desired. This type of wing fits in well with a parasol mounting.

The basic aerodynamic proportions of the high-performance duration and semi-scale types of petrol model are given for convenience of reference on the page diagrams, Figs. 10 and 11.

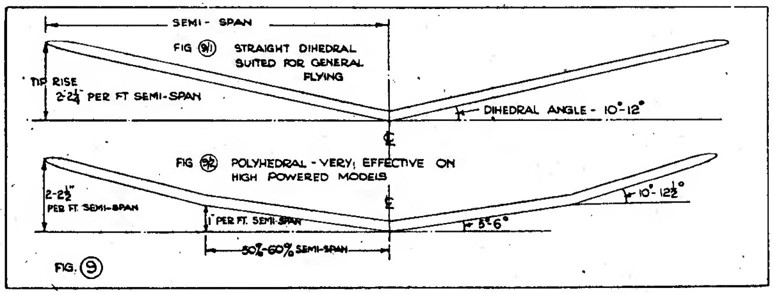


FIG. 9

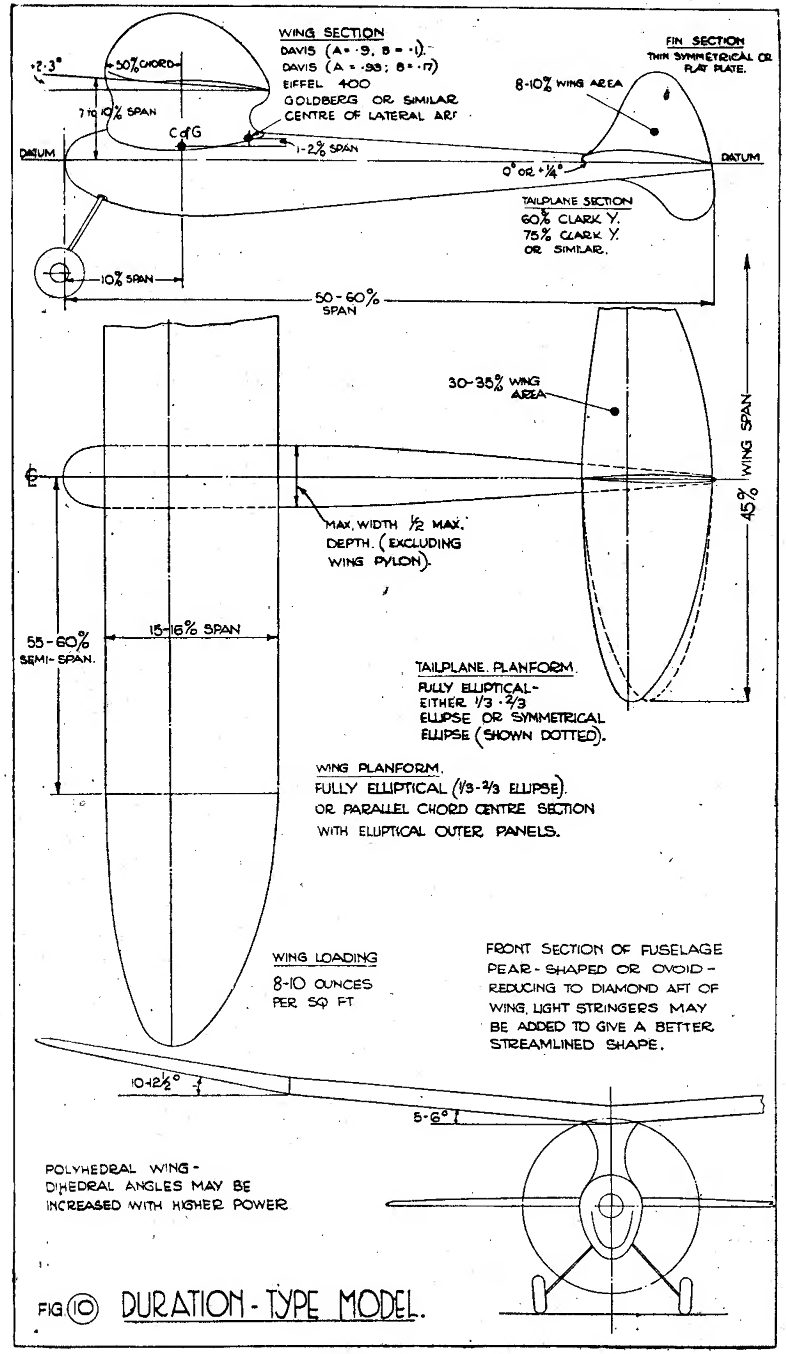


FIG 10 DURATION - TYPE MODEL.

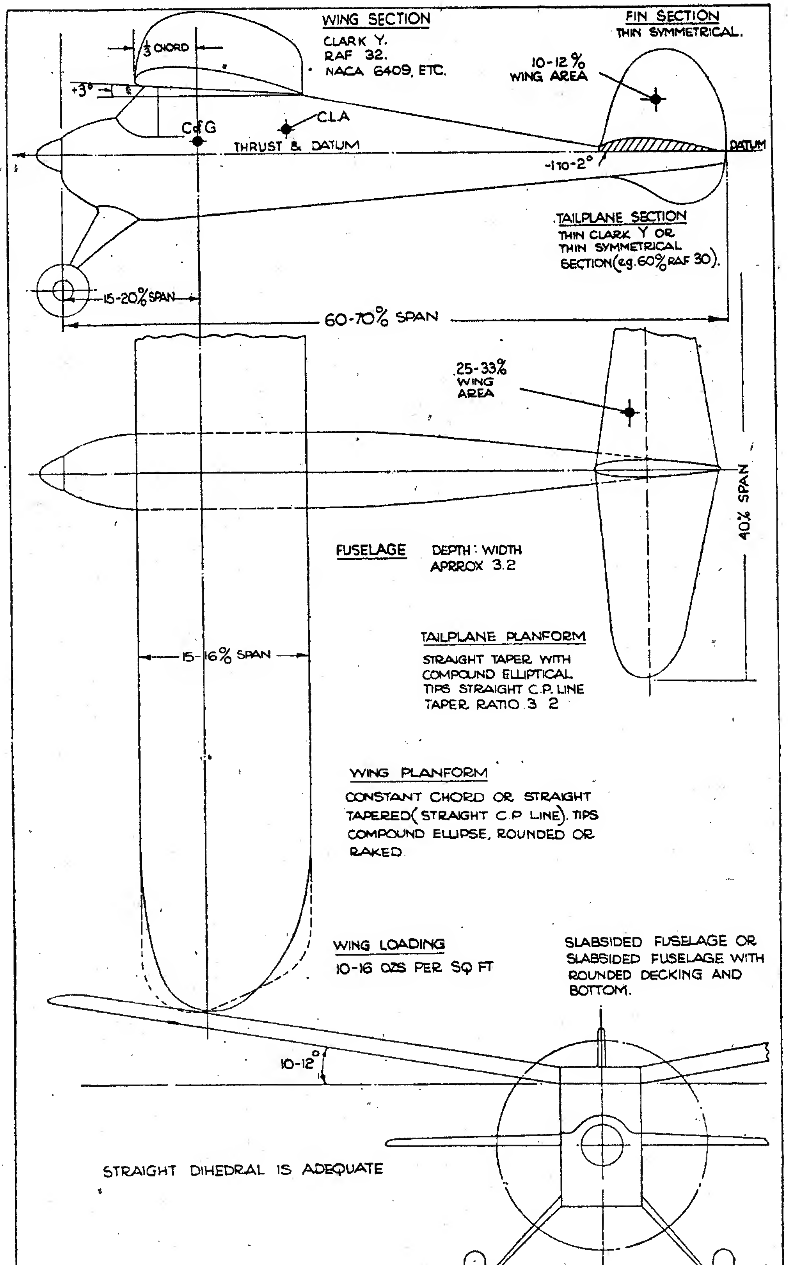


FIG (11) SEMI-SCALE TYPE

CHAPTER III

SIZE OF MODEL

THE overall size of a petrol model depends primarily upon the size and power of the aero-motor to be used. Even this is not a strict definition, for quite small models may be fitted with powerful motors, giving an increased performance. In such cases the wing loading is also increased, due to the greater weight of motor, hence the landing speed is increased and also the liability to damage.

Again the characteristics of aero-motors of similar sizes vary considerably. Some motors are lighter than others; some give more power, all for the same size or capacity. In this country before the war the petrol model movement had not reached the stage where definite classes of sizes of miniature aero-motors had been established. The majority or the early commercial motors were imported from America and were mainly of the popular 9 c.c. and 6 c.c capacity. Later followed smaller motors, both British and American, of 2·3 c.c., 3 to 4 c.c., 7·5 c.c., etc.

Since 1940 the capacities of all American miniature aero-motors have been quoted in cubic inches, whilst in this country the standard cubic centimetre (c.c.) unit has been retained. Conversion from one system to another for quick comparison involves the use of conversion factors and calculation. To avoid this the instantaneous conversion scale on page 15 should be used, which gives accuracy well within the limits required by the modeller.

Duration types

The best criteria for deciding the size of a duration type petrol model are wing *area* and wing *loading*. The proportions of the model then follow from Fig. 10.

The wing loading should be kept within 12 ozs. per square foot. About 8-10 ozs. per sq. ft. is the figure to be aimed at for duration work. The area can be roughly determined from the examples below, which give typical model sizes for various sizes of aero-motors. Knowing the weight of the aero-motor to be used, and the weight of the coil, condenser, timer, and flight batteries the structural weight of the model can be worked out and the structural design completed accordingly. It is best, wherever possible, to design a model around a specific motor, rather than around a particular *size* of motor, although a good design can often be powered by various types of motor, even of slightly different size, and difference in trim necessary being taken up during the flight testing stage. The examples given below are worked out for various motor *sizes* since there is little indication as yet of the characteristics of the various post-war commercial motors.

Small aero-motors of 1·5 to 2.5 c.c. capacity

Although attractive from the point of view of economy in material, handy size and relatively low cost, the weight problem is rather acute with such models. Structural weight must be kept to a minimum, otherwise the resulting wing loading will be too high for safety. Another disadvantage is that although the bare weight of the motor is small the weight of the coil, condenser, and flight battery is quite out of proportion, generally being greater than that of the motor.

Such models are not suited to the beginner, or the modeller with little "petrol" experience, but are interesting to tackle later when the trickiness of a motor of this size is better appreciated and the modeller's constructional and flying skill greater.

Wing area—220-240 sq. ins.
Total weight—14-16 ozs.
Motor weight—2 ozs.
Coil, condenser and flight batteries—4-6 ozs.
Airscrew diameter—8-10 ins.

Motors 2·5 to 3·5 c.c.

Apart from the fact that a small motor of this size may tend to be somewhat tricky this size of model is easy to build and handle and allows a good strong structure within the weight limits.

Wing area—300 sq. ins.
Total weight—1-1½ lbs.
Motor weight—3-4 ozs.
Coil, condenser, and flight batteries—4-6 ozs.
Airscrew diameter—9-11 ins.

Motors 4 to 5 c.c.

An excellent class of model for the beginner and of a size large enough to have a good aerodynamic efficiency. With weight to spare, by careful structural design, full streamlining may be introduced, as in the larger sizes of models. Below this size streamlining means extra weight, which can only be gained by sacrificing local strength.

Wing area—440-480 sq. ins.
Total weight—2-2½ lbs.
Motor weight—6 ozs.
Coil, condenser and flight batteries—10-12 ozs.
Airscrew diameter—10-12 ins.

Motors 6 to 8 c.c.

A relatively large contest model which can be made extremely efficient and have an outstanding performance. Motors of this size and over are relatively trouble free and the greater total weight permissible means that a larger coil can be carried, with consequently a more reliable ignition system.

Wing area—650-700 sq. ins.
Total weight—2½-3½ lbs.
Motor weight—8-10 ozs.
Coil, condenser and flight batteries—5-7 ozs.
Airscrew diameter—12-14 ins.

Motors 8 to 10 c.c.

The large contest model, which needs plenty of packing space, but has excellent aerodynamic efficiency and a fine performance.

Wing area—700-900 sq. ins.
Total weight—3½-4 lbs.
Motor weight—9-10 ozs.
Coil, condenser and flight batteries—6-8 ozs.
Airscrew diameter—13-15 ins.

Semi-scale models

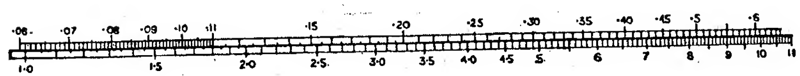
The semi-scale type of model designed primarily with an eye on performance should have the same characteristics as the above, depending upon the size of motor used. The typically 'British' semi-scale models of pre-war days were mainly designed around three distinct sizes of motor, 9 c.c., 6 c.c. and 3-4 c.c. Corresponding average figures for size and weight were: span 7-8 ft., weight 4-6 lbs.; span 6 ft., weight 3-4 lbs.; span 4ft. 6in., weight 2 lbs.

Most of these models were heavier than they need have been, with the result that a stronger structure was needed to absorb all landing loads—a vicious circle, for added strength generally means added weight. Where performance is not necessarily the main aim the figures for duration models may be taken, with the total weight increased by about 10 per cent., except for the smallest class, which already has a wing loading of optimum value.

Larger models with motors of 15 c.c., 25 c.c., or greater may be built, but are mainly individual efforts and beyond the scope of this present book.

INSTANTANEOUS CONVERSION SCALE

CUBIC INCHES (cu. ins.)



CUBIC CENTIMETRES (c.c.)

This scale may be used to convert motor capacity in c.c. into capacity in cu. ins., and vice versa. Corresponding values are read off on opposite sides of the scale. The range may be extended by multiplying top and bottom by 10, or by 100, as desired.

CHAPTER IV

STRUCTURAL FEATURES

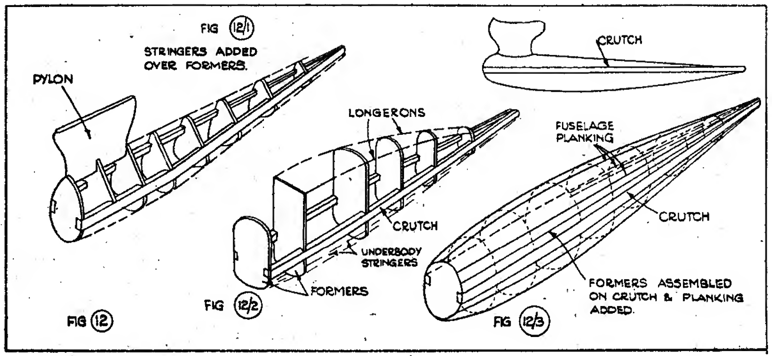
The components to be considered are :—the wings, fuselage, tail-plane, fin (and rudder or trim tab) and undercarriage. Motor mounting is dealt with in a later chapter.

The material used for the airframe is chiefly balsa, with certain harder woods, such as bass, pine, spruce and birch for highly stressed members, the proportion of these woods increasing as the size (and total weight) of the model increases. Jap tissue, bamboo tissue, silk, and certain proprietary cellulose coverings and special papers, such as planefilm, silkspan, etc., are all used for covering, depending again upon the size of the model and the availability of these products.

Fuselage construction

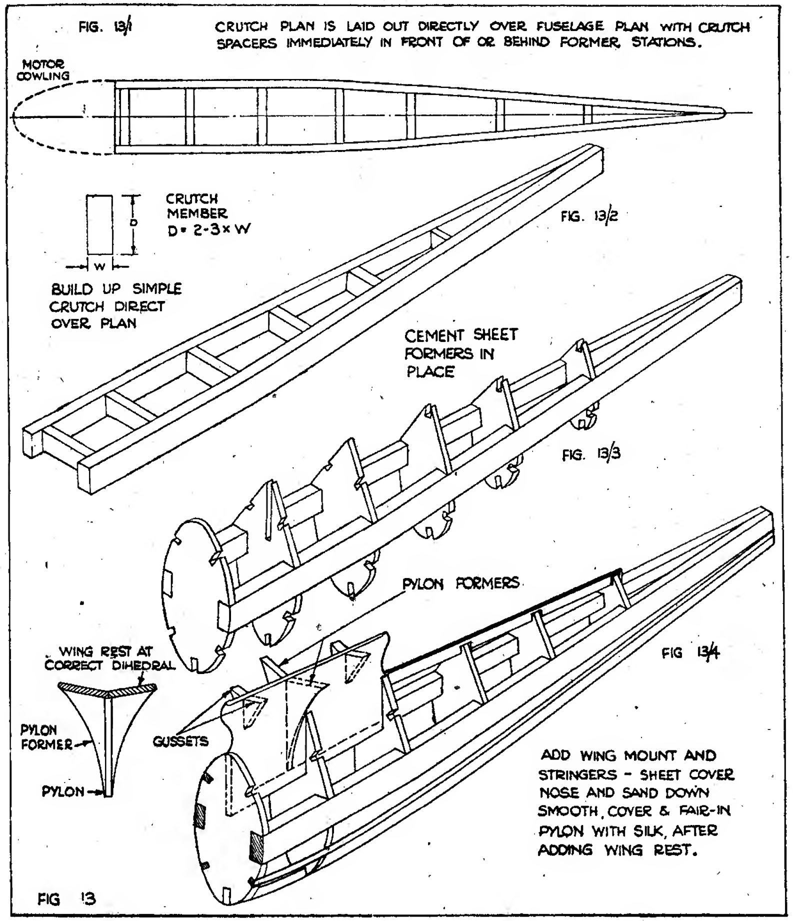
All duration types, and nearly all the semi-scale types lend themselves admirably to a modern form of fuselage construction in which the basic part is a crutch, around which all other members are located. There is also an even more modern technique in which the fuselage is made of a pure monocoque structure of moulded plastic materials. A separate chapter—Chapter V—is devoted to this.

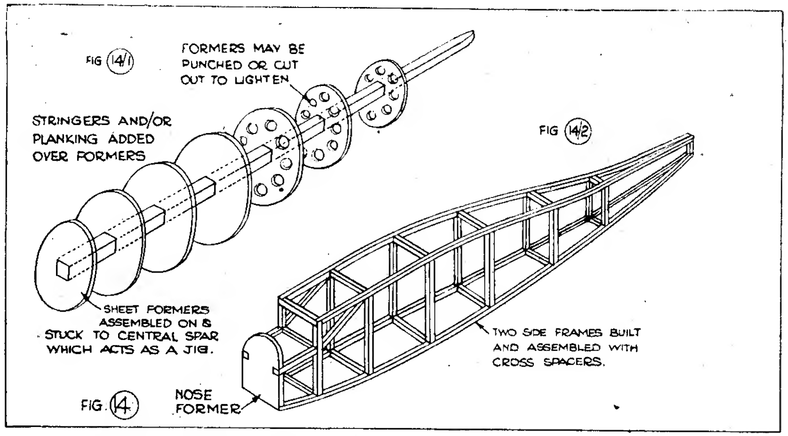
The assembly of a fuselage around a crutch makes for rapid construction and reduces any liability to distortion or error. The top (or bottom) line of the crutch can also be made the datum line which considerably simplifies the checking of rigging angles on the completed model. The principle of crutch construction is shown in Fig. 12, applied to a duration type fuselage, 12/1, a semi-scale fuselage, 12/2, and a planked semi-monocoque fuselage, 12/3. The crutch is the strongest member in the airframe and all stresses should be transmitted to it.



The construction of a duration-type fuselage with pylon wing mounting is shown in stages in Fig. 13, and by following this through the reader should appreciate how this form of construction can be applied to almost any type of fuselage. The crutch plan is laid out directly over the plan view of the fuselage. Crutch members should be of large cross-section, the depth of the members being two to three times their width, 13/1.

All formers are cut from sheet and are locked and cemented in place against the crutch spacers—one crutch spacer for each former position—13/3. The sheet pylon wing-mount is then cemented in place and the fuselage stringers added—13/4, after which the wing mount may be completed and the fuselage sanded down ready for covering.



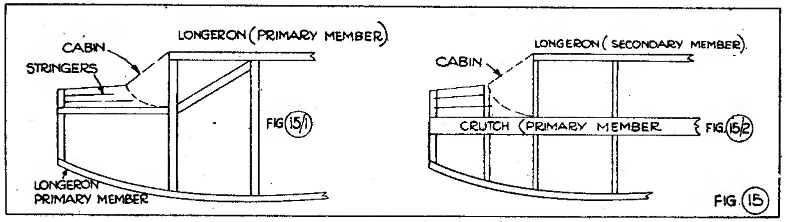


Suitable material sizes for any new design are best decided by reference to plans of previously successful models. As a guide to crutch member sizes: $1\times\frac{3}{16}$ spruce or birch is suitable for large models; $\frac{1}{2}\times\frac{3}{16}$ spruce for medium sized models; $\frac{3}{4}\times\frac{1}{4}$ hard balsa is also suitable for medium sized models; $\frac{1}{2}\times\frac{3}{16}$ balsa for smaller types and $\frac{3}{8}\times\frac{3}{16}$ balsa for baby models.

There are many other forms of fuselage construction which may be used, but none is as simple and accurate as the crutch method. Method 14/1 has been widely used for streamlined fuselages where the formers are assembled on and cemented to a central jigging rod, and for simple slabsided fuselages the orthodox rubber-type open girder structure of 14/2 is sometimes used. Most pre-war British models were of this latter type, using birch or spruce for the longerons (balsa on small models only), hardwood or balsa spacers and ply master formers in the fuselage forebody.

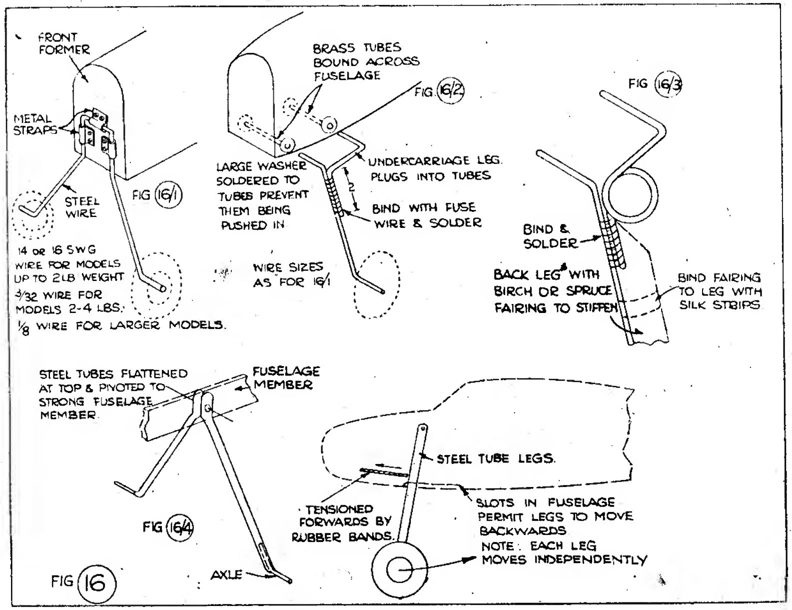
The use of a fuselage crutch obviates the inherent weak spot in a fuselage with a cabin in that the main fuselage members are continuous from nose to tail—Fig. 15/2, and not broken as in normal box construction—15/1.

In all classes of models the forebody of the fuselage should be sheet covered, after installing the various electrical and timing equipment and/or making provision for access to this for maintenance, etc.



1/16 sheet balsa is adequate for the smaller sizes of model, with thicker balsa sheet for larger models, in proportion. Medium and large slab-sided fuselages should have the nose portion sheet covered with 1 mm. ply.

The undercarriage installation is often something of a problem, for it must be reasonably clean from the aerodynamic point of view and also capable of absorbing heavy landing shocks and guarding the air-screw from damage.



The American system is simply to employ a wire cantilever unit bolted or sewn to the nose former of the fuselage (invariably of plywood on *all* petrol models)—see Fig. 16/1. The size of the wire chosen depends upon the weight of the model, typical diameters being indicated on the diagram.

This straightforward type of undercarriage is reasonably satisfactory for small and medium sized models, but is inclined to be too flexible on larger sizes, particularly if the wire is not of really first quality material (spring steel). It also suffers from the defect that it is not demountable for transport to and from the flying field.

A similar system used by the writer for medium sized models is shown in 16/2. This simply plugs into brass tubes bound across the fuselage and is readily detachable. It is also more rigid than the first system and is quite suitable for models up to 4 lbs. in weight, using the wire diameters specified. For larger models a further modification of this—16/3—can be used, although this unit is not particularly clean.

An excellent cantilever undercarriage for really heavy models, especially those of the semi-scale type, is that developed by D. A Russell and shown in 16/4. The legs are of mild steel tubing flattened and pivoted to an anchor post integral with the fuselage at the top. Each leg has an independent fore and aft movement in slots in the fuselage side or bottom. Normally each leg is tensioned forwards by elastic bands and only moves backwards under landing loads against the pull of the elastic bands. The travel is limited by the length of the slots, and the rate of travel, or shock absorption, by the tension and number of bands used.

The general tendency now is to use much cleaner undercarriages as distinct from the wire tripods with spreader bars and auxiliary braces common on British models of the mid-1930 era. Telescopic legs with coil spring shock absorbers are quite unsatisfactory, due first to the bounce of the spring and, secondly, the shimmy of the wheel and leg in anything but a landing with absolutely no drift. Even then on a large model shimmying may develop.

Wing construction

The wing structure of most petrol models is generally similar to that of the orthodox rubber driven model, only to a larger scale. Since low aspect ratio wings are favoured on duration types two-and multi-spar construction is widely used. Hard balsa of large cross section is strong enough for small and most medium sized models, although spruce spars should be used on large models. Large section leading and trailing edge spars should always be used, to ensure a good aerofoil section and make covering easier. The trailing edge should generally be of balsa of generous width (about $\frac{1}{8}$th chord) or built up from 1 mm. ply as in 17/4 on really large wings. Leading edge material must be strong, for this member will receive a lot of knocks. An excellent form of leading edge construction is shown in 17/4, where a false balsa leading edge is used and a wrapped hardwood sheet leading edge cemented around this and to the ribs. This can still be kept light and is amazingly strong

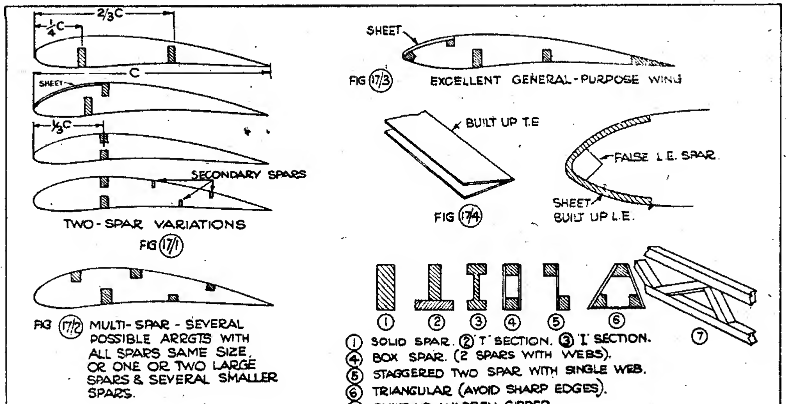
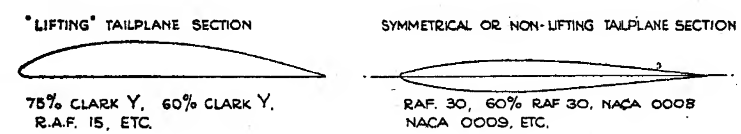


FIG 17

Tailplane Construction

The tailplane is generally of monospar construction, this mainspar being located at the point of maximum depth of the ribs and extending about 80 per cent. of that depth. The trailing edge should be built up of sheet balsa, with a balsa or hardwood leading edge.

FIG 18



Structurally a tailplane with an aerofoil section having a flat undersurface is to be preferred, since this can be built flat on the working board and easily checked for warps, etc. Thus even with a "non-lifting" tail a section with a flat undersurface and cambered upper surface should be used, rigged as shown in Fig. 3/2.

The tailplane must be as light as possible, yet strong enough to stand up to any knocks it may expect and also be rigid and absolutely free from any warps or tendency to warp. This is generally taken care of by adequate spar sizes and careful covering, being sure not to apply too many coats of dope.

Fin Construction

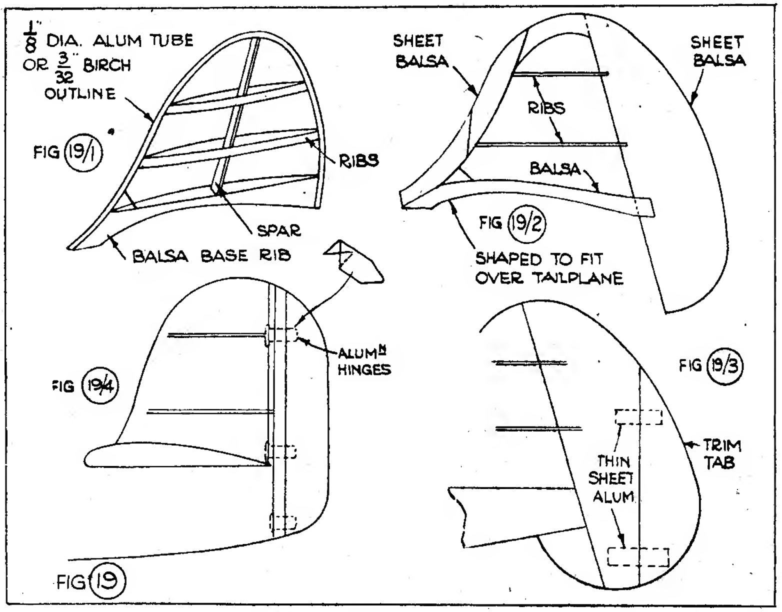
The fin is a simple structure, but may be divided into two parts on some designs, the main fin and an under-fin. In such cases the under-fin should be built integral with the fuselage—of sheet balsa on small models or built up as for the main fin on larger models.

Two very simple forms of fin construction are shown in Fig. 19/1. The outline is bent from aluminium tube, or $\frac{3}{32}$ or $\frac{1}{8}$ sq. birch steamed to shape and sanded to a round section, and the mainspar and ribs cemented in place. The base rib should be of thick sheet balsa to give a firm fixing to spars and outline, which can also be gussetted and/or sewn to this rib.

Another type of fin which has much to recommend it is shown in 19/2. The outline is of balsa, with wide sheet trailing edge. A balsa or hardwood spar can be used and the $\frac{3}{4} \times \frac{1}{16}$ balsa rib faces cemented in place.

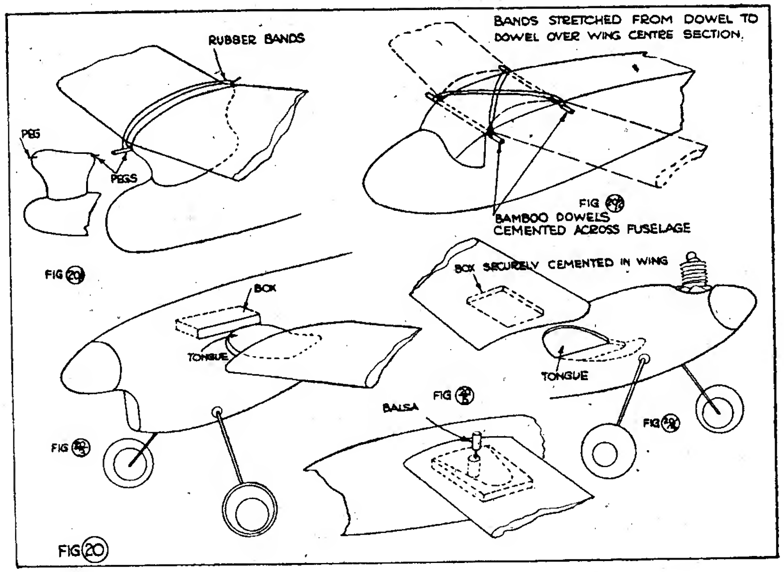
Movable trim tabs or rudders are an added complication and may often be avoided by arranging that the whole fin can be offset as required to give a turn. Figs. 19/3 and 19/4 show simple methods of incorporating a trim tab in the fin structure.

To make the model as reasonably crashproof as possible all components liable to damage should knock off in a heavy landing, such as occasioned by striking an obstacle, etc. Motor mounting is considered separately later. On a parasol or high wing type the wings should be held in place by strong rubber bands, which may be fitted externally as in Fig. 20/21 and 20/2, or internally, if desired, by a suitable arrangement of hooks.

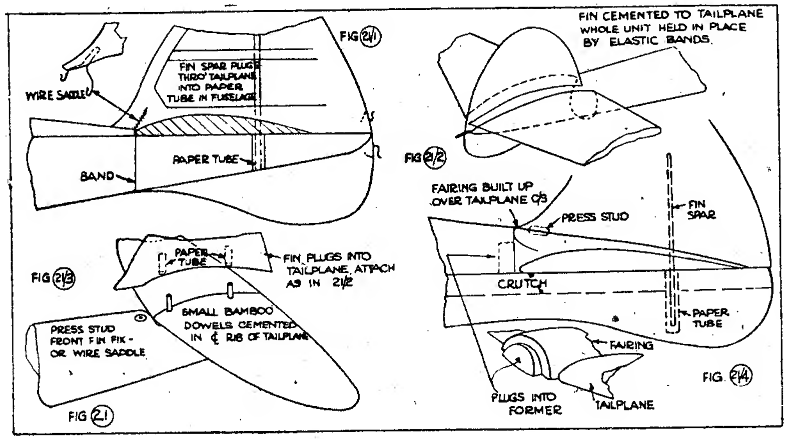


For shoulder-, mid- and low-wing positions the tongue and box fitting, so popular on large gliders, is ideal. The tongue may be fitted to the wings with the box in the fuselage—20/3, or the box in the wings and the tongue in the fuselage—20/4. Whichever method is used the tongue should be tapered to allow the wings to knock off smoothly both forwards and backwards without damage to the box, and dihedral angles should always be built into the tongues.

The wing should be a tight push-fit in position, otherwise there is a danger of it vibrating loose in flight. To overcome this a hole may be drilled through the wing and tongue and box when in position—20/5—this hole being plugged with a balsa "pin". This will prevent the wing working loose, but in a heavy landing, or when the wing receives a knock, the pin will shear, allowing the wing to knock off without damage to the structure. The balsa pin is then simply replaced ready for the next flight.



Some simple tail fittings suitable for most models are shown in Fig. 21, all of which are reasonably flexible in the event of a crash-landing. Similar schemes may be used with a fully streamlined fuselage, cutting away the rear section of the upper fairing down to the crutch, seating the tailplane on the crutch and fairing in the centre section to conform to the lines of the fuselage.



Covering.

For the smallest size petrol models tissue covering should be used throughout, to keep weight to a minimum. For greater strength and durability the fuselage can be double covered. On all other models lightweight silk should be used whenever possible. The "substitute" material for silk is bamboo tissue, which can be obtained in various grades (and strengths) according to the size of model to be covered. Bamboo tissue is rougher than silk and tears more readily, although somewhat easier to apply, covering technique being the same as that for ordinary Jap tissue. Certain proprietary brands of covering material are now replacing silk to some extent, although also in short supply at the present time.

Tissue covering can be applied to quite large models, double or treble covering to give additional strength where required. Thus the fuselage of a 5 ft. span duration type could be treble covered with tissue, the tail unit single or double covered, and the wings double covered with the centre section treble covered.

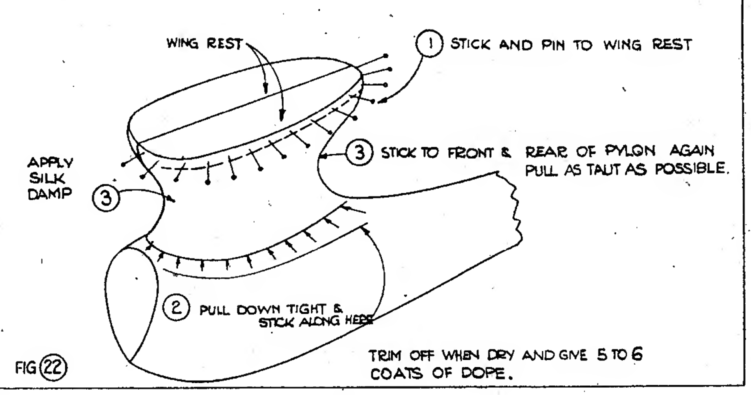


FIG 22

For fairing-in the pylon on such types silk is the only suitable medium, although other materials can be used in an emergency. The application of silk covering to a pylon wing mount is shown in Fig. 22. The silk should be applied damp, one piece for each side, and stuck to top and bottom with thin Durofix. Make sure that it remains securely stuck whilst drying. By applying five or six coats of dope to this covering the result is an amazingly strong and rigid structure.

The application of silk covering follows commonsense rules—the main thing to bear in mind is that the covering must be pulled *taut.* It is no good relying on the dope to tighten up slack silk covering—often the reverse is the case. For covering curved members tackle the job in strips or sections, as with tissue covering. It is often helpful to

(*Concluded on page* 29)

CHAPTER V

MOULDED PLASTIC COMPONENTS

THE application of plastics to model aeroplane construction has now reached the stage where it can be considered alongside normal construction for such components as fuselages for petrol models and large gliders, and is definitely superior for such items as duo-curved motor cowlings, etc. In general plastic construction is, as yet, heavier than orthodox construction, although this varies considerably with the materials employed.

The system of plastic construction developed in the United States is essentially that of winding strips of gauze and/or paper around a shaped form or mould, crossing the grain of alternate layers of strip and binding them together with a plastic cement. Once set the plastic shell is withdrawn from the mould or form and can be finished by sand-papering and doping and adding any internal strengthening members, such as formers or bulkheads, necessary.

The strength of the monocoque shell so formed depends upon the strength of the materials used and the bonding strength of the plastic cement, and also upon the number of layers. The usual practice is to increase the thickness of the shell at regions subjected to the greatest stresses and thus produce an economic structure of the desired strength at a weight which compares quite favourably with a planked balsa monocoque structure.

Plastic construction may be extended to wings and tail surfaces, but at present is mainly limited to the fuselage members mentioned above.

Since the method of construction is similar whatever materials are used these materials will be described first and the general working procedure for making (i) a complete motor cowling and, (ii) a complete monocoque fuselage detailed later. From these descriptions the reader should be in a position to apply this type of construction to any component of any particular model.

Materials

Method (a).—Strips of newspaper, about $\frac{3}{4}$-1 in. wide (narrower at curves of small radius), with alternate layers at right angles.

Method (b).—Alternate layers of newspaper strip and gauze strip, each following layer being at right angles to the one before it, or each layer at 45 degrees to the one before it.

Method (c).—As for (*b*), but using strips of bamboo tissue instead of newspaper.

Method (d).—One layer of bamboo tissue or newspaper strip, followed by two layers of gauze or linen tape. The first layer of gauze or linen is laid on at 45 degrees to the *paper* strips, doubled back and the

second gauze or linen layer applied at right angles to the first *gauze or linen* layer. Succeeding layers follow in the same order.

Each layer is bonded by a plastic cement—of which there are several brands on the market in America and it is to be expected that similar substances will soon be available in this country. The chief type recommended by the Americans is called Weldwood, which, applied thickly between each layer, sets in a really rigid fashion and is immensely strong. Its chief disadvantage is that it may tend to become brittle. Other bonding agents have been used, amongst them a mixture of equal parts of dope and cement, with a small quantity of castor oil added as a plasticiser to remove any tendency towards brittleness. About one ounce of castor oil per quart of mixture as above is generally adequate. A greater proportion of plasticiser tends to make the bonding agent sticky and delays setting.

From the writer's own experiences any form of moulded construction employing newspaper strips as a base tends to be very strong and rigid, but far too brittle to withstand shock loads. Such loads, instead of being absorbed in the structure, generally split the component. The same fault is apparent when the bonding agent is brittle when set. Methods (*b*), (*c*) and (*d*) are generally excellent for monocoque fuselage construction, whilst (*a*) can be used for lightly stressed fairings, etc.

The main disadvantage of all these schemes is that during setting the shell contracts on the form and is often very difficult to remove. Collapsible forms are an advantage here, although this unfortunate tendency can be reduced somewhat if the right type of bonding agent can be found. At present no definite rules can be laid down for this and readers interested in this method of construction are advised to experiment with their own materials, using the materials outlined above as a basis and following the general working procedure below.

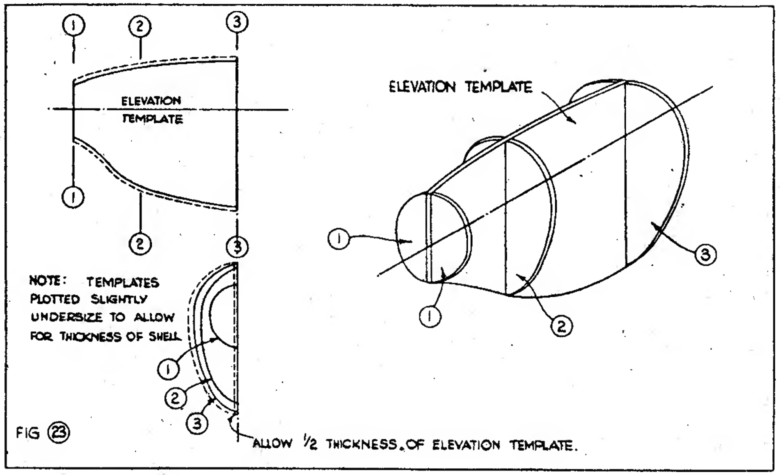


FIG 23

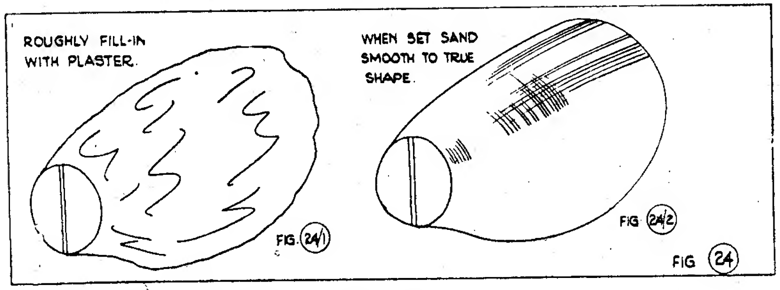


FIG 24

Motor Cowlings and Similar Components

First an accurately shaped form or core is required on to which the various layers of the shell are to be wound. This core can be carved from solid wood, although a much simpler and quicker method is to mould it in plaster around a number of card patterns. The method of laying out and assembling a set of card patterns for a typical cowling shape is shown in Fig. 23. Other materials can be used instead of card—1/16 sheet balsa being particularly easy to cut and cement in place.

Note that all patterns must be plotted slightly undersize—this being to allow for the thickness of the final shell. The stages of finishing the core or form is then shown in Fig. 24. Roughly fill in and mould to shape—24/1—and leave to set. When completely dry sand down smooth to the correct shape with fine sandpaper. Plaster of paris, mixed with water or a very fine glue solution, is excellent for filling in.

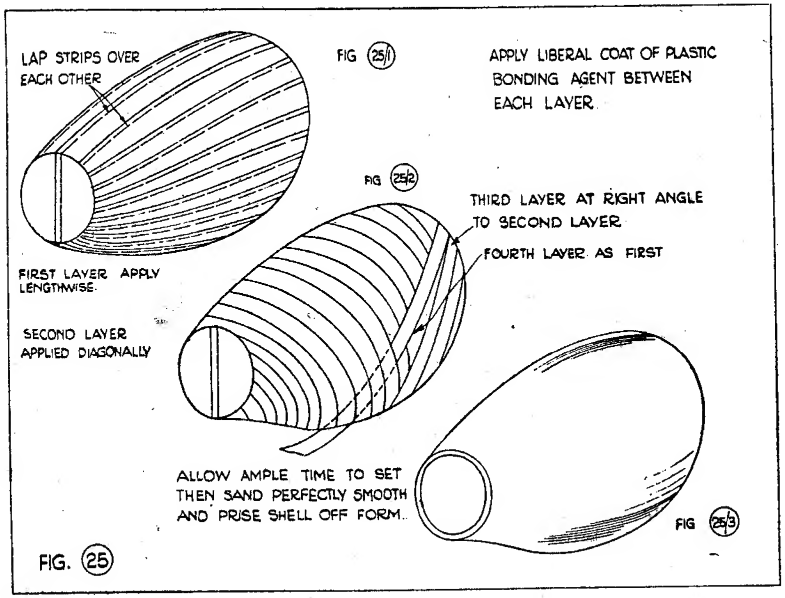


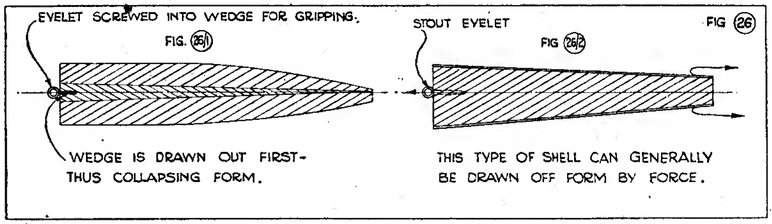
FIG. 25

Before attempting to add the paper strips grease the form well with vaseline to prevent the shell sticking to it. When using a solid wood form the first layer of paper should be applied wet and not soaked in the bonding agent or plastic cement, as an additional safeguard against sticking. All wood forms should be given a coat of shellac varnish and wax polished before greasing.

The application of the various strips should be clearly understood from Fig. 25, which illustrates this step by step. Note particularly how each *strip* is lapped over the one before it, the amount of overlap being one-third to one-half the width of the strip. About six to eight layers should be ample for most motor cowlings, and four to six layers for lightly stressed fairings. Highly stressed regions could have an additional two or four layers.

Plastic monocoque fuselage

Fuselage construction is essentially similar, except that the preparation of the form or core is more tedious. In nearly all cases this is best made from a block of wood, or several wood blocks glued together to give the required size. A more elaborate form may be prepared, in sections, with a centre portion which can be withdrawn completely, collapsing the rest of the form, the remaining pieces being so designed that they can be shaken out of the shell.



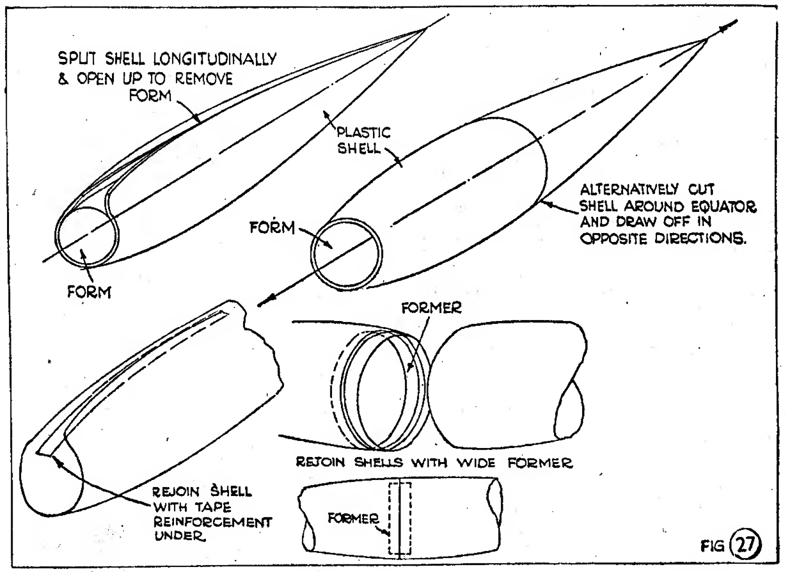
Normally, however, the contraction of the shell during setting is such that it is amost impossible to withdraw the core, even on a tapered body with no change in curvature—26—although this can be done by brute force. The best method for normal fuselages is to split the shell, either along the top or around the greatest circumference, and then withdraw the form, cementing the shell together again at the split with a tape reinforcement under. These points are best shown diagrammatically—see Fig. 27.

The main points to bear in mind with this type of construction are:—

(i) Be sure that the form is well greased and that there is no chance of the shell sticking to it.

(ii) Soak each strip in the bonding cement and then apply quickly and evenly without wrinkles.

(iii) Always lap the strips of each layer over one another for greatest strength.



(iv) Using Weldwood as a bonding cement a layer of this can be applied between each layer for even greater strength. A *thin* layer of the bonding cement should, in any case, be applied between each layer, whatever agent is used.

(v) Once the required number of layers have been added over the form leave *for at least* 48 *hours* to set before attempting to remove the shell. If the shell is removed before it has properly set and contraction has ceased, it will warp badly and the moulding will be useless.

(*Continued from page* 24)

work with the silk dampened beforehand, as it can then generally be pulled tighter, and large coned sections covered in one piece.

Opinions vary as to the best type of adhesive to use. Some modellers use ordinary water-soluble glue, but this is apt to be messy and may tend to come unstuck in damp weather. The writer recommends the use of thin Durofix—about one part Durofix cement to one of thinners, or any other *slow drying* cellulose cement of similar properties.

Doping is carried out as for any other covering. Surfaces should be pinned or weighted down whilst drying and, after the final coat, left for at least 24 hours in this state to ensure that the dope has thoroughly set and will not continue to tighten and possibly warp the structure. The first two coats of dope fill in the pores of the covering and pull it tight. Succeeding coats add less weight and only go to increase the weatherproof qualities. However, each coat plasticises the coats applied before, so wings and tail surfaces must be weighted down to dry after *each* coat.

CHAPTER VI

MOTORS AND MOTOR MOUNTING

As we have seen in Chapter III, the size of the model depends upon the choice and availability of the motor, particularly if a good performance is required. Whilst a more powerful motor will almost certainly increase the rate of climb the flying speed will also be increased due to the greater weight and with it the risk of crashes. A low-powered motor, on the other hand, might not give enough thrust to give a good climb, or even maintain level flight, unless operating at maximum revs. It is always desirable to fly a petrol model with the motor operating below maximum revs., as this reduces wear on the working parts and tends to increase the efficiency of the airscrew. Full power flights should only be attempted when competition rules call for maximum duration following a limited motor run.

At the time of writing the manufacture of miniature aero-motors has temporarily ceased, due to priority of war work, but it is anticipated that this will be resumed both in this country and America in the near future. In this book we are concerned with the motor as a complete unit, ready to fit to the model. Detailed operating and maintenance instructions are generally supplied with commercial motors and the makers' advice should always be followed. Always use the fuel mixture specified by the manufacturers for any particular motor, bearing in mind that British seasons are somewhat cooler than corresponding American seasons.

Using the correct mixture of petrol and oil is one of the most important factors in preserving the working life of a miniature aero-motor, especially since in the majority of cases the piston is lapped into the cylinder. Undue wear, arising from the use of too little oil, will weaken the compression, causing loss of power and faulty running. Heavy oil must be used as this does not break down so quickly at the temperatures met in the cylinder. In fact, good quality oil is more important than the grade of petrol, as it affects the moving parts of the motor. High grade petrol should be used, whenever obtainable, but *not high octane fuels* which have a relatively heavy proportion of tetra-ethyl lead or similar anti-knock dope. Such dopes cause corrosion of the cylinder walls and pitting of the piston due to the active lead compounds left after combustion.

Another practice to be discouraged is taking the motor apart. This should only be done when necessary for cleaning, and even then great care taken not to scratch or score the piston or cylinder, and all joints should be made gas-tight with "gaskets" of Durofix or sealing compound. For further information on the subject of motors and motor maintenance the reader is referred to the various specialised books and articles which have already been published.

A lot of confusion is caused by the fact that the "size" of miniature aero-motors, i.e., the *capacity*, is given in cubic centimetres (c.c.) for British and Continental motors, and in cubic inches (cu. ins.) for all American motors. The scale on p. 15 gives instantaneous conversion from cubic inches to cubic centimetres, and *vice-versa*, and should be useful in comparing American and British motors.

The capacity of a motor is an indication of the power which can be expected from it, that is, the greater the capacity the greater the power, and *vice-versa*. This is not strictly true, for a well-designed motor of a certain capacity may give greater power than a larger motor of inferior design. Another point to be borne in mind is the motor speed at which optimum power is obtained. In nearly all cases miniature aero-motors are of the two-stroke type and there is a certain minimum motor speed at which they can operate. Below this they are not reliable, tend to four-stroke and are prone to stop altogether under slight variation of load (as might be given by a change in flying altitude of the model). At the other end of the speed scale an extremely high rate of revolution increases the wear on the moving parts and tends to make the airscrew inefficient. For normal operation a motor speed of between 3,000 and 4,000 r.p.m. appears the best.

Another point where similar sized motors differ considerably is in weight. Within resonable limits this is not so important since the correct C.G. position can generally be arrived at by shifting the flight battery fore or aft, as required. Thus correct balance can be obtained without the use of ballast. Unless specifically designed around a particular motor, of which all component weights are known, and the C.G. position *designed* around this data, provision should be made in all designs for shifting the flight batteries to balance for trim.

Motor mounting

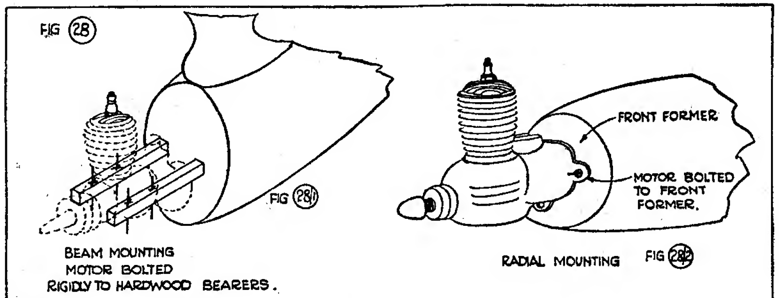
Motor mounting is a subject which has received relatively little attention in America, standard practice in that country being to bolt the motor rigidly to motor bearers, which are themselves rigidly secured to the fuselage. Adjustment for downthrust and sidethrust is achieved by inserting shims or packing between the motor and the bearers and offsetting the whole motor on the mounts. Typical examples for radial and upright mountings are shown in Fig. 28.

In the case of a crash landing the motor is likely to be severely damaged, since it is highly probable that the crankshaft will be bent or snapped before the motor is torn off the bearers. The British, and in particular Col. Bowden, have pioneered the knock-off or detachable motor mount, which allows the motor to knock off in a heavy landing and thus minimises the risk of damage.

Two forms of detachable motor mounts are shown in Fig. 29. The first is simple and easy to construct and the principle of its use should be clear from the drawings. The rear face of the motor mount, of plywood, matches the front former of the fuselage. A smaller plug-in portion screwed and/or cemented to the mount face locates in a similarly

shaped cut-out in the fuselage former. The motor is bolted or screwed to the bearer arms and the whole unit is held in place by elastic bands stretched between hooks, as shown.

In the event of a hard knock the motor mount, carrying the motor rigidly attached to it, is displaced from the fuselage and thus minimises the shock load absorbed by it. The tension of the rubber bands must be adjusted so that the whole unit is held securely in place and is free from vibration with the motor running, yet can knock out when a heavy load is applied upwards, as would be the case in the event of the nose or airscrew striking the ground.



N.B. MOST MINIATURE AERO MOTORS ARE DESIGNED FOR BEAM MOUNTING. A FEW ARE MADE FOR EITHER BEAM OR RADIAL MOUNTING.

The whole motor mount unit, which is shown built up from ply and birch in the diagrams, can be cast in light metal, such as electron, or can be of mixed wood and metal construction. For example, the webs, shown of ply, could be of aluminium with pressed flanges for greater rigidity.

Packing for sidethrust is simply inserted between the rear face of the mount of the front fuselage former. Once the required amount has been found this can then be cemented in position.

The method of 29/2 is a simple extension of the American principle. The bearer arms are rigidly secured to the fuselage and the motor is bolted to a specially shaped aluminium or dural plate which fits over the bearers. The bearers should be notched, or preferably have small stops screwed to them, so that any fore and aft movement of the mounting plate is impossible. The plate is then lashed down to the bearers with rubber bands, which act as shock absorbers in crash landings or allow the motor and mounting plate to knock off the bearers under a heavy shock.

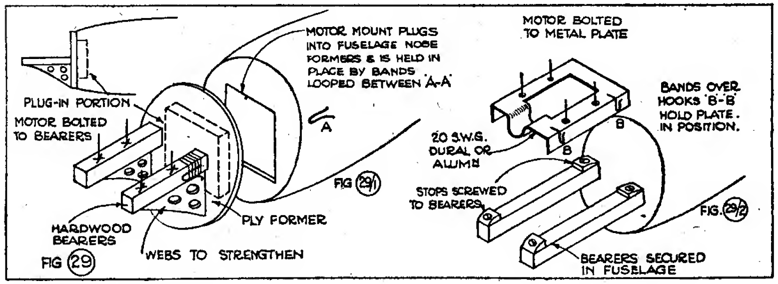
In this case any sidethrust should be incorporated in mounting the motor on the mounting plate. Downthrust is simply given by inserting packing slips under the rear of the plate, between it and the bearers, and the depth of the rear stop should be so designed to ensure that the mounting plate cannot ride over it. At the same time the stops should be shallow enough to allow the mounting plate to knock free when necessary.

These are but two forms of detachable motor mounts and many variations and other forms are in existence. The above are well tried and have proved extremely successful in practice and the beginner is advised to start with them.

In comparing the British and American methods the writer strongly advises that a detachable or knock-off mounting be employed in *all* petrol models, especially as our flying weather is generally rougher than that of the Americas.

All motors have a certain vibration when running and this vibration is transmitted through the airframe. Provided that the motor and the airscrew are well balanced there is no need to worry about this, although some authorities do advise that a packing of rubber be inserted between the motor and the bearers (or mounting plate) to minimise this. Cases of extremely bad vibration can generally be traced to:—

(i) Motor not balanced correctly, or
(ii) Airscrew not balanced, or
(iii) Motor firing unevenly, or
(iv) Mounting not strapped securely to the fuselage.



Upright or inverted?

Considerable controversy has arisen over the respective merits of running the motor in an upright or inverted position. Mainly this affects the scale and semi-scale enthusiast who wishes to enclose the motor in a scale cowling. From the design point of view the first consideration is the thrust line position, and secondly, fairing-in the motor.

Motor cowling has not received a great deal of attention in the past and often, particularly on duration types, the motor has been mounted completely uncowled. This is ideal from the point of view of simplicity and accessibility of the motor for adjustment, but bad from the aerodynamic standpoint. An uncowled motor has quite a high drag and the aerodynamic efficiency can be greatly improved by completely fairing-in the motor, or enclosing it in a cowling of the right shape.

When the motor is cowled-in in this manner provision must be made to ensure an adequate flow of cooling air over and around the cylinder, and also the needle valve, air intake and timer controls must be readily accessible for adjustment, and choking for starting. It must

also be easily possible to observe the level of the fuel in the tank (or measure this if the tank is not transparent) and also to refill the tank.

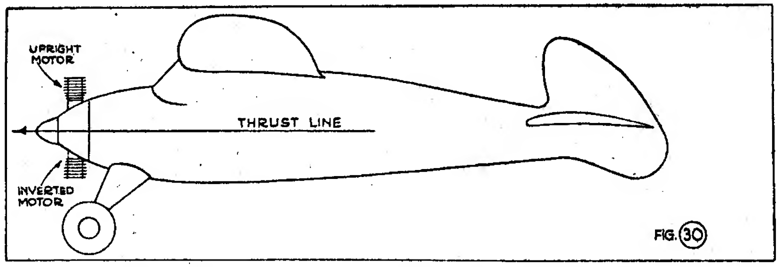


FIG. 30

A further point is that bad cowling may *increase* the drag of the motor unit. From the aerodynamic point of view too many cowlings, although having a smart appearance, are nothing more than a "bucket" to trap the air and have a very high drag figure. Air led in the front of the cowling to cool the motor should be led out again smoothly at the rear of the cowling, without striking against a face perpendicular to the direction of flow, or being left to "find its own way out." This generally means a system of light baffles and is somewhat difficult to arrange in the limited space associated with a miniature aero-motor.

The best solution is generally as follows :—

Duration types should incorporate a cowling enclosing the body of the motor, leaving the cylinder in the airstream. All controls can be located outside the cowling for convenience.

On *semi-scale* types the same method can be adopted, or the motor mounted in the inverted position and the cowling design carefully worked out. With enclosed controls, also, part of the cowling should be hinged, or quickly detachable, for access, or the controls extended to come just outside the cowling itself.

Thus in most duration and some semi-scale types it does not really matter whether the motor is upright or inverted, unless the thrust line is some distance from the centre line of the fuselage. In cases such as these the logical mounting of the motor will be obvious.

When aiming at efficiency and the choice between an upright or inverted motor is purely arbitrary—Fig. 30—the final choice should be left to the motor. The majority of present day commercial motors generally run better in the upright position and tend to oil up the plug when re-arranged to run inverted. And if supplied as an upright motor, the tank and air intake arrangement, etc., must be adjusted for inverted running. Some upright motors, in fact, will not run in the inverted position.

With the type of motor designed to operate either upright or inverted the choice is more open and the design of the model will generally decide, although unless the motor is specifically designed to operate in an inverted position it is generally best to run it in the upright position.

CHAPTER VII

AERO-MOTOR ELECTRICS AND ACCESSORIES

OVER ninety per cent. of motor running faults can be traced directly or indirectly to the electric system, that is, to the coil, battery, spark plug, condenser or wiring. Of these the flight battery, spark plug and wiring are the chief offenders, in that order.

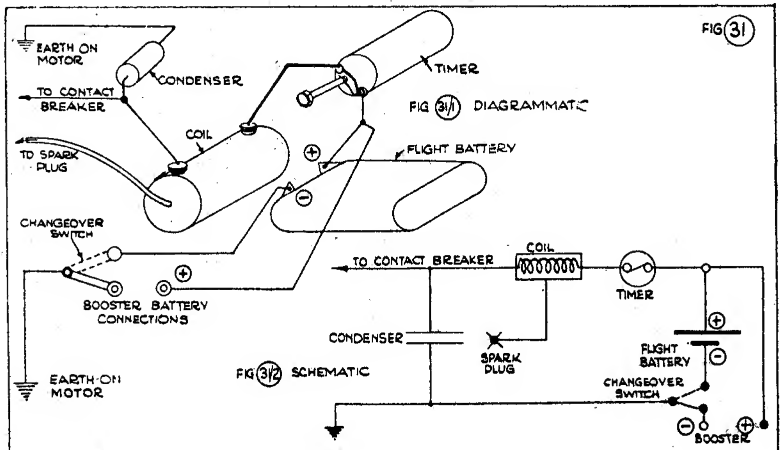
The typical electrical system of a petrol model is shown in Fig. 31, of which the components are :—

(i) ignition coil,
(ii) condenser,
(iii) flight battery,
(iv) spark plug,
(v) booster-battery connections,
(vi) change-over switch,
(vii) ignition time-switch,
(viii) wiring.

The *coil* used should always be of the best quality available, suitable for the type of motor and plug employed, and as large as possible within the weights allowed in the design. The *condenser* should likewise be of best quality and of the correct capacity matching the coil.

Ordinary flash-lamp batteries are usually carried as flight batteries, but have a very short life and must be replaced after about ten minutes motor running (maximum). These are generally heavier than the motor itself in the smaller sizes of motor. To keep weight down "Penlite" cells are often used on the smallest class of model, but such cells are very weak and apt to be unreliable. It is better to use standard batteries, stripping off all the card container and as much other material as possible to cut the weight down to the minimum.

FIG. 31



Although in regular use dry batteries of this type are generally unsuited for petrol model work, except in large models, where larger cells can be carried, as the weight question is not then so important. (Actually in such cases the *relative* weight of the flight battery is less.) The proper type of flight battery is a miniature accumulator, giving a pressure of 4 volts and weighing between 2 and 4 ozs. Such accumulators are on the market in America and many have been individually produced in this country. They will probably appear as a commercial article here soon after the war.

The object of the booster-battery is to provide electrical energy for starting and warming up and running the motor prior to the commencement of the flight. A normal accumulator is used for this, which can easily supply all the current needed, and the flight battery is then only operative during the take-off and the flight itself.

Starting should *never* be attempted on the flight batteries alone, for this will simply drain them of all their energy, leaving none for the rest of the flight. Using a miniature accumulator as a flight battery the booster battery can also be used to charge the flight battery between flights and thus maintain it at optimum capacity. The change-over switch is incorporated in the system so that the booster battery is always feeding the motor circuit during starting and running up, leaving the flight battery disconnected. Operating the switch then disconnects the booster battery circuit and puts the flight battery in circuit without breaking the flow of current through the coil.

Booster-battery connections are simply wander plug type, plugging into sockets secured to the fuselage side. A switch should be incorporated in the leads from the booster accumulator to the plugs, which can be switched "off" when the plugs are withdrawn and thus avoid any possibility of short-circuiting the accumulator should these plugs be dropped on to damp grass.

The ignition switch is a necessary part of the system, being installed to break the ignition circuit and thus stop the motor after a predetermined time. Otherwise on a full tank the motor might run for anything up to twenty minutes, carrying the model many miles and out of sight of the launching point. The danger of unabandoned petrol model flying is stressed in a later chapter.

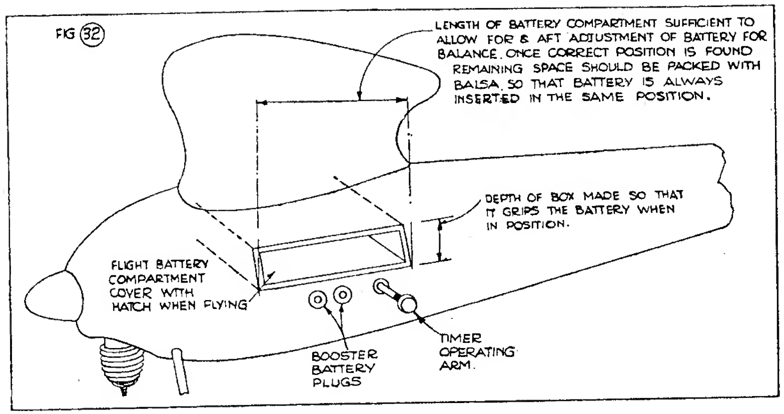
There are two chief types of timeswitch:—clockwork and airdraulic. The clockwork unit can be made quite light and extremely reliable. It is the best type for precision timing. Several commercial articles were available before the war and will again be produced shortly. The airdraulic timer is extremely simple, operating on the principle of a spring loaded piston being forced into a cylinder with a small air leak. Such types may be adjusted over a wide range of time and are very light. Timeswitches are discussed more fully in Chapter IX.

Of the wiring it may be said that all high tension wiring should be kept to the minimum length, and multi-strand wire used instead of

"solid". That is the connection between the coil and the spark plug should be as short as possible and of stranded wire, well insulated. The other wiring should be tinned copper, also well insulated. Here, although the insulating properties are not so important, a covering does prevent, or delay, any chafing which may arise from vibration.

All wire joints should be well soldered and the joints confirmed as good before being accepted as satisfactory. Battery connections may take the form of crocodile clips gripping the battery lugs, which connection is quite good electrically so long as clips and lugs are kept clean, and makes for easy disconnection and re-connection as required.

The coil and condenser should be grouped as close to the motor as possible. In many cases it is possible to mount the coil and condenser on the actual motor-mount, which is excellent in many respects, as it makes the whole motor unit complete and detachable as a unit. Failing this the coil and condenser can be secured in the fuselage immediately behind the nose former.



The compartment for the flight battery must be so designed that the battery can be slid forwards or backwards to balance the model as required; the connections must be flexible to allow for this, e.g., using the crocodile tips already mentioned; it must be easy to remove and replace the battery, preferably without having to dismantle any part of the model; and the battery must be *secure* so that there is no chance of it shifting its position during flight, *or during a heavy landing*. A suitable layont for a typical duration model is shown in Fig. 32.

All the electrical controls should be conveniently grouped together on one side of the fuselage—the port side if right-handed, and the starboard side if left-handed—or on top of the fuselage behind the wings. That is, the timer, change-over switch and booster battery connection sockets should be arranged in one convenient spot, as this considerably simplifies starting routine.

CHAPTER VIII

RIGGING, TRIMMING AND FLYING

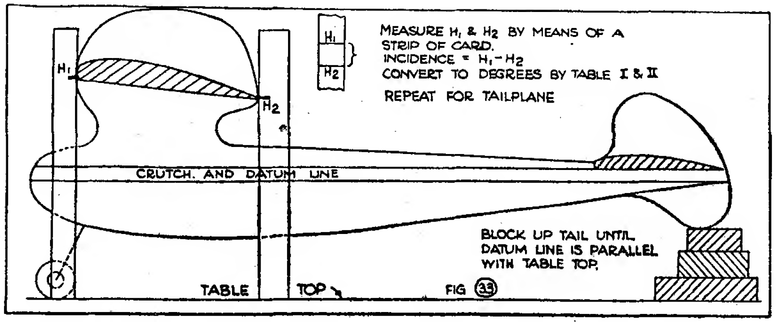
THE flying of any type of petrol model should be approached in four stages:—

(i) Checking of rigging and balance.
(ii) Gliding tests.
(iii) Flight tests under restricted power.
(iv) Trimming tests with increasing power.

Of these four stages the first is too often hurried, or even omitted, with the result that crashes result which might otherwise have been avoided.

Checking of rigging and balance

Assemble the model and check the rigging incidences of the wings and tailplane. On a model with crutch construction this is simply done, as in Fig. 33/1, standing the model on a table and blocking up so that



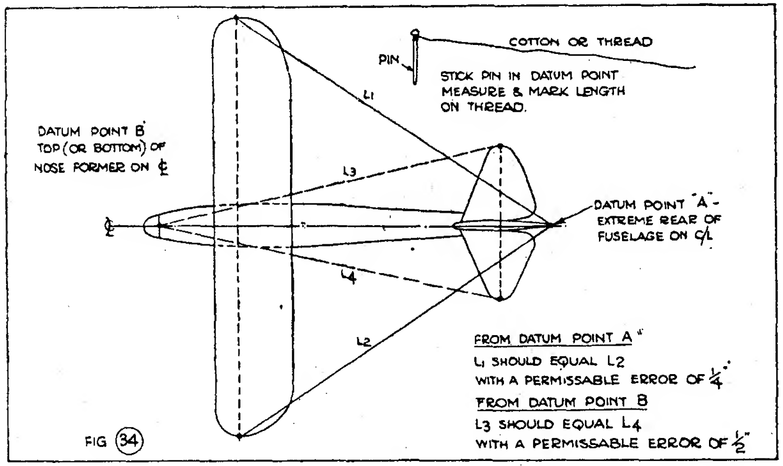
the datum line is parallel with the table top. Measure the distance of the leading and trailing edges of the tailplane and wing mount, or straight edge under the wings, as shown, and finding the angular setting of the wings and tailplane by subtraction of corresponding measurements. This is expressed in inches (decimal fractions) and the table given on the back inside cover will give this incidence in degrees corresponding to the chord of the section measured. This is then the rigging incidence measured with respect to the crutch line, which is invariably taken as the datum line.

The correct incidence is generally specified on the plan, if not the following generalised examples may be taken as a guide.

Duration types

Lifting tail (i.e., tailplane carrying part of the load):

(i) C.G. position 50 per cent. average chord. Wing incidence plus $\frac{1}{2}$-2 degrees; tailplane incidence plus 2-3 degrees *relative to the zero-lift* chord of the tail section, i.e., with the normal Clark Y or thin Clark Y type section, tailplane incidence 0 degrees *relative to bottom line of section.*



(ii) C.G. position 66 per cent. chord. Wing incidence plus 2-3 degrees; tailplane incidence plus $\frac{1}{2}$-1 degree, relative to bottom line of section.

Tailplane not lifting (i.e., carrying no load in normal flight attitude). C.G. position one third chord from leading edge. Wing incidence plus 2-2$\frac{1}{2}$ degrees; tailplane incidence at that rigging angle corresponding to zero lift of the section employed under flight conditions.

These generalisations should be studied carefully in conjunction with the section on downwash and rigging in Chapter II.

Once assured that the rigging incidences are correct the model should be viewed as a whole to check alignment of surfaces. The wings and tailplane must be square with the fuselage, and this can simply be checked with a length of cotton and a pin as shown in Fig. 34.

The wings and tailplane must also line up correctly when viewed from the front. This is best checked by laying the model on its back, as in Fig. 35, and checking the various points noted.

Finally, make sure that all surfaces are true and free from warps.

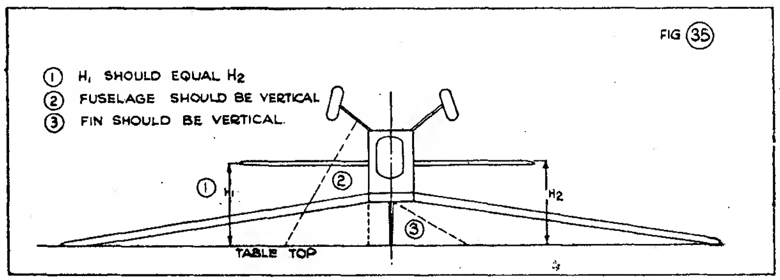
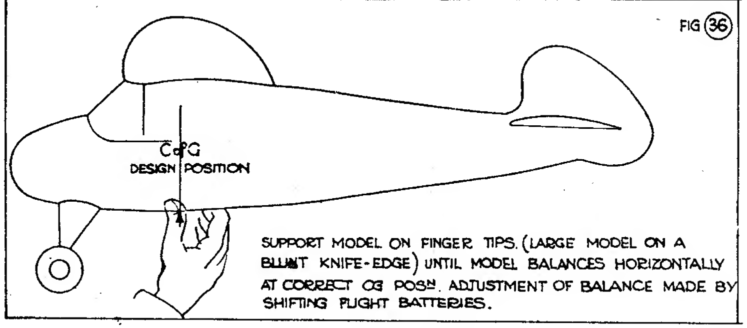


FIG 36



Any suspected warps in the wings or tailplane can be proved by laying these components on a flat board.

There now remains adjustment for balance, i.e., ensuring that the C.G. (centre of gravity of the model) is correctly placed. Support the model by the finger-tips under the wings, or under the fuselage, in a vertical line with the design position of the C.G. and adjust the flight battery position by moving backwards or forwards until the model balances horizontally—Fig. 36.

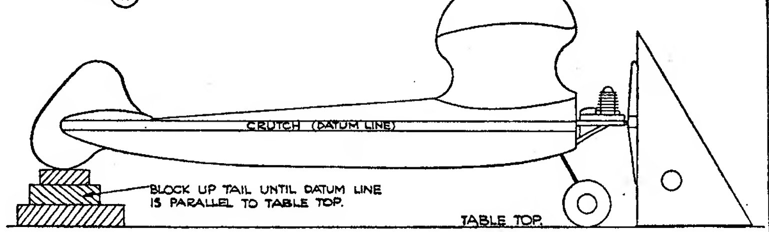
Check also the line-up of the motor—Fig. 37—propping up the fuselage so that the datum line is parallel with the table top and using a set-square to check the inclination of the airscrew, and therefore the thrust line to the horizontal, i.e., the datum line.

Use of sidethrust and downthrust

Neither sidethrust nor downthrust may be necessary on a duration type petrol model, torque being taken care of by the generous dihedral angle of the wings and the model allowed to spiral in the direction of its natural turn under power, and any stalling tendency which would normally be cured by adding downthrust can be taken up by tightening the circle. This is trimming to get the utmost useful power from the motor. In most cases, however, particularly in this country, both downthrust and sidethrust are used in moderation during trimming, and this method is somewhat safer.

Most miniature aero-motors rotate the airscrew in an anti-clockwise direction, viewed from the front, so that under power torque

FIG 37



tends to bank the model to the left, giving a natural left turn under power. With large power, and consequently large torque, this natural bank and turn may be too steep, so the motor is packed round or offset so that the thrust line is inclined slightly to the right of the (presumed) line of straight flight. According to the degree of offset so will the natural left turn first become wider, then straight flight under power will result, and finally a right turn under power, by successively increasing the sidethrust.

A straight flight under power is not desirable, neither is an excessive torque force, or excessive sidethrust, giving a steep turn in one direction or the other. The best plan is to incorporate a small amount of sidethrust in the original set-up—about 2 degrees is ample—and then let the model take up its natural turn under power, whether this is to the left or the right. If anything there is a slight preference for a left turn under power, although even with no sidethrust a parasol type will often have a natural turn to the right under power if the rudder or trim tab is slightly offset to give a smooth right circle on the glide.

If a model shows a tendency to turn in one direction—and the line-up is correct, with the surfaces free from warps—it is better to let it circle in that direction rather than try to get it to turn the other way.

Gliding Tests

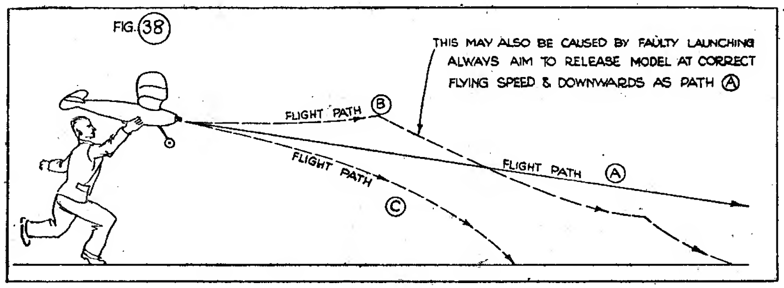
Gliding tests should simply be a verification of the rigging angles and balance, i.e., practical tests proving the initial design layout. If the design calculations are correct, and the model is correctly rigged and balanced, it should glide correctly. However, a certain proportion of every design is so much estimation and any errors involved are ironed out at this stage. The more that has been left to "guesswork" the more there is to adjust during these glide tests.

Choose a calm day or evening for these tests and carry them out over long grass if possible, so that if the model does come in steeply it will not dash itself against hard ground. Always lock the airscrew on the crankshaft *so that it comes to rest in a horizontal position when the motor stops*. This saves a lot of broken airscrews, even in normal flying, the only disadvantage being that with the airscrew in this position starting the motor is more awkward. If particularly dubious about the initial gliding tests the whole engine may be replaced by a mass of the same weight and the trim found with this. The glide tests must then be repeated with the motor in position to make sure that the different shape of the motor and airscrew does not affect the trim, and any further slight adjustments necessary then made.

Launching a model during these tests is mainly a matter of knack, this being gained by practice. Small models can be launched with one hand, holding the fuselage under the C.G.; large models require two hands, the left hand under the C.G. and the right hand near the tail. The launching procedure is slightly different and success will only come after constant practice.

The object of the launch is to release the model in a slightly nose-down attitude (roughly corresponding to its gliding angle) and at its correct gliding speed. Whenever there is any wind launching must always be carried out dead into the wind. After leaving the hand(s) the model should glide steadily down on an even keel, as in **Fig. 38**, path A. If the model rises and dips, as path B, or tends to nose down rapidly, as path C, the trim is incorrect and must be adjusted accordingly.

In the case of flight path B the flight battery must be moved forwards, i.e., the C.G. brought forwards slightly, and in the case of flight path C, the C.G. must be moved back slightly by shifting the flight battery backwards.



The model may also be trimmed by the tailplane, increasing the tailplane incidence *slightly* to cure the stall of flight path B, and decreasing the incidence *slightly* for flight path C. However, this method of trim is more liable to abuse and is not recommended to the beginner.

Once the correct adjustment has been established a number of similar glide tests should be repeated to ensure that the model is *in perfect trim for gliding*.

It is best to trim the model to make wide right circles on the glide, this being given by offsetting the trim tab or rudder slightly to the right.

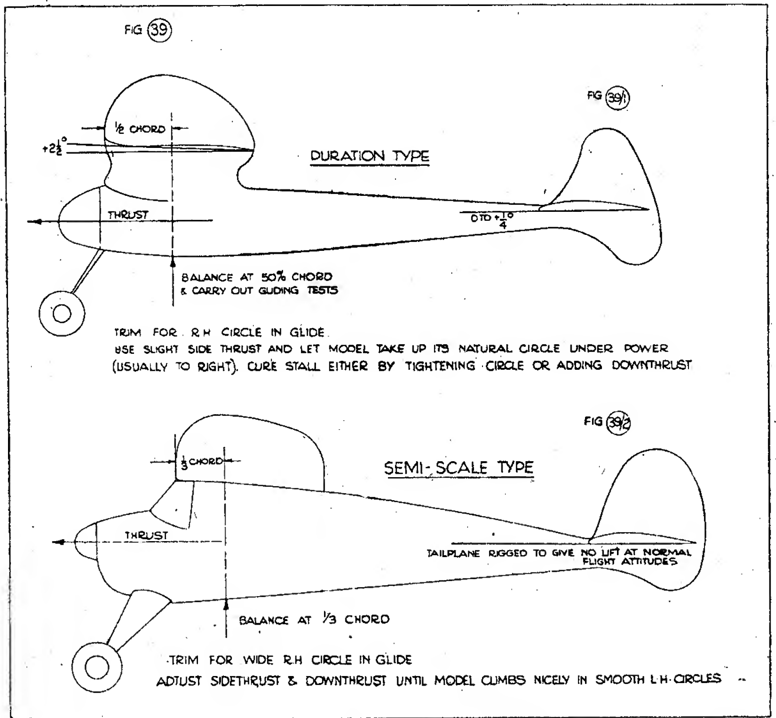
As a rough check on the gliding flight a model with reasonably clean lines should cover about 50-60 feet before touching down when launched from shoulder height *in still air*.

It needs considerable practice to be sure of obtaining the right launch for a hand-launched glide from level ground, and the "feel" of the model whilst still in the hand(s). Gliding trim is subject to further slight adjustments after the initial power tests, for a true glide cannot really be observed until the model is about 100 ft. from the ground and is left to pick up its own gliding angle.

Restricted power flights

The object of these flights is twofold—first, to get the model up to a sufficient height to check that the adjustments made during hand-launching for the glide are correct (or to make any further adjustments necessary), and, second, to study the effect of engine-on conditions.

These tests should be made with the motor throttled back to about half the normal operating speed and the duration of power run limited by the time switch to about 20 seconds. For preference small and medium sized models should be hand-launched whilst larger models can take off a reasonably smooth surface, being assisted and steadied by holding on to one wing tip and running along with the model, releasing when air-borne.



As a safeguard against stalling a temporary downthrust packing equivalent to about 5 degrees, can be installed on the motor mount.

Under these flights the model should climb steadily, but slowly, in wide circles and be at a sufficient height when the power cuts for the model to pick up its natural gliding angle, so that the true glide can be observed. Motor speed can be slightly increased, if necessary, until this height is reached.

Any further adjustments to the glide can then be made. That is, the circle can be widened or tightened, as required, bearing in mind that if originally trimmed for a *straight* glide, which is the only practical attempt on hand-launched glides, tightening the circle will cause the model to speed up slightly due to the loss of lift in the bank, and it may be necessary to move the C.G. back slightly to prevent this circling glide from becoming too steep.

Under the restricted motor power for these tests no unstable effects due to the application of thrust should be noticed, unless there is an inherent weakness in the design.

Trimming with increased power

It now remains to complete the trimming of the model, concentrating solely on the line-up and setting of the motor. The above tests have established the glide as correct.

This final stage will depend to some extent upon the type of flying required. Nice steady flights, with no spectacular or outstanding performance, are given by using downthrust in excess of that value for maximum efficiency. However, excessive downthrust may be dangerous, especially under full power.

Short power flights should be attempted, removing the downthrust a bit at a time until none is left. Then increase the power output (i.e. the running speed) of the motor slightly on each successive flight until, any signs of a stall under power appears. Normally, as soon as this happens a small amount of downthrust should be added and the tests continued, right up to full power, adding more downthrust as this becomes necessary. Provided that this is done in easy stages, and with a motor run limited to about 10 seconds, there is little danger of damaging the model by a crash.

High-efficiency duration types, and particularly those with parasol wings, generally take up a steep climbing turn under power and little or no downthrust is necessary.

Throughout these tests with progressivly increasing power any tendency towards a steep bank with little or no gain in height must be cured at once. Assuming the design is correct, such a fault is generally due to (a) excessive torque or excessive sidethrust, or (b) excessive rudder offset. This will generally be obvious from the direction of bank, and corresponding corrections made. Any adjustment to rudder at this stage means re-checking the glide, but the fault will almost certainly lie with the thrust line position.

The final solution to all trimming and flight testing problems is plenty of experience, coupled with patience and an understanding of the reason for making each adjustment. Until considerably experienced at least, *only make one adjustment at a time* and be thorough over detail.

Special Note.—On pylon-type duration models with *high power* the following rigging angles may be necessary to prevent a loop under power :—Wing, 0° ; tailplane, 0 to $\pm\frac{1}{4}°$. In general with such models the greater the power the smaller the rigging incidence of the wing.

CHAPTER IX

CONTROLLED FLYING

THE petrol model can, if flown in a thoughtless manner, become a danger to person and property and serious accidents may result which can only have grave repercussions on the whole movement. That is to say, a large model, weighing several pounds, is a source of danger if it is allowed to fly away and "land" in a built-up area or a busy street. The ignition switch which limits the motor run, and thus the duration of flight, to a safe figure, is therefore ***a most essential feature of every petrol model.***

There is also the consideration with the duration type petrol model that although the motor run is limited the model is so efficient that it may easily soar out of sight in a thermal current. Apart from the dangers mentioned above there is also the fact that a valuable model, and an equally valuable motor, may be lost.

This has led to the development of flight spoilers, or *dethermalisers* as they are termed, which come into operation after a set time and bring the model down to earth. On a normal flight, i.e., a non-soaring flight, the dethermaliser is not brought into use, but should the model still be airborne after, say, ten minutes (this time being dependent upon wind drift and estimated as the maximum safe duration for that particular flight), the spoiler comes into use and brings the model rapidly, but safely, to earth.

For example, flying on a day when a flight of six minutes or more would result in the model drifting completely out of sight the spoiler would be set to operate at about 5 to 5½ minutes and thus, if the model did start soaring away, would ensure that it would land before passing out of sight, and possibly being lost. Or, if the flying field is so located that flights of, say, four minutes or more would mean the model landing amongst houses, the dethermaliser could be set to bring the model down, should the need arise, before it reaches the "danger area".

The dethermaliser is an essential part of a high-efficiency duration type petrol model if this model is going to be flown in weather when thermals or upcurrents are present. This generally means any fine day between the hours of ten in the morning and about six at night.

Any dethermaliser unit consists essentially of an adjustable timer, which can be set to operate a trip with a range of from two to ten minutes and a flight spoiler.

The timer

One time-switch can be made to operate both the motor stop (i.e., breaking the ignition circuit) and the flight spoiler trip, but it is generally better to use a separate timer for the dethermaliser. The same type of timer can be used, that is, clockwork or airdraulic or any other mechanical unit which is reliable and is capable of easy adjustment.

Austin type (commercial) airdraulic timers are generally excellent for this work—or a modified Kodak (camera) time-switch. Clockwork timers developed especially as ignition time-switches for model aeroplanes generally have a maximum duration of two minutes and require some considerable modification to increase this to ten minutes. The writer favours the airdraulic type, based on the principle of the Austin timer, which can be made extremely light and is quite reliable. Some commercial varieties of these should be on the market soon after the war.

Spoilers

The most effective method of bringing a model down quickly is to spin it in. Unfortunately, although this is an ideal method of dethermalisation it is liable to damage the model when it strikes the ground. Thus the method used on some rubber models of turning the rudder sharply and forcing the model into a spin is not directly applicable to petrol models. There is, however, an American scheme which is most effective in spinning the model in and yet giving it a chance to recover before striking the ground. This is illustrated in Fig. 40.

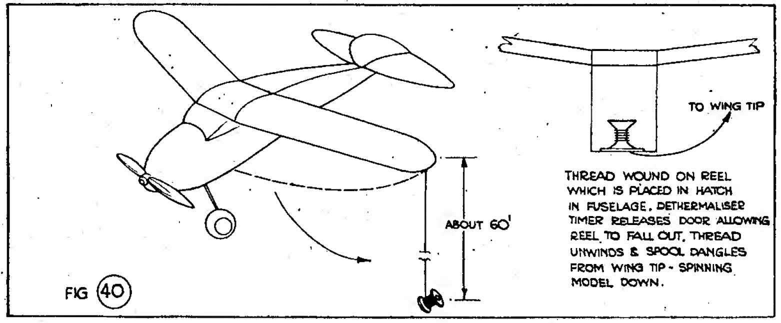


FIG 40

Attached to one wing tip is a length of cotton (about 60 feet long), the other end of the cotton being securely tied to a cotton spool. The slack of the cotton is wound on the spool, which then fits in a small compartment in the underside of the fuselage and is kept there by shutting a trap door. The dethermaliser timer operates a trip which releases the catch holding the trap door shut, which then opens under the weight of the reel, allowing it to fall free, unwinding the cotton until the reel is suspended from one wing tip, some 60 ft. below it.

This causes the model to spin and it continues to spin until the reel hits the ground. The model then begins to recover from the spin—now being relieved of the weight attached to the wing tip—and the 60 feet altitude it has to recover in is sufficient for it to make a good landing. Should the spool get caught up in being dragged along the ground the cotton immediately breaks, so that whatever happens once the spool has hit the ground the model is free to recover.

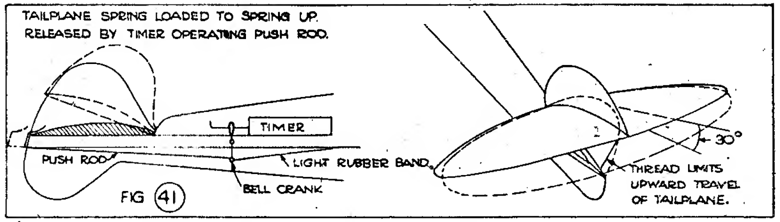


FIG 41

Another successful American scheme is illustrated in Fig. 41, in which the whole tailplane springs up to a large negative angle (about 30 degrees) when released by the dethermaliser timer. This results in the model stalling violently and then either settling down to a rapid descent *on even keel* or in a lazy flat spin, depending upon the characteristics of the design (of the model itself). The former is ideal; the model simply lands on its undercarriage, somewhat more heavily than usual, with hardly any forward run. Even if the second possibility does take place a flat spin is far less dangerous than a steep spiral dive or rapid spin and the worst damage likely to result is a broken airscrew.

A third type of spoiler, also American, consists of applying an airbrake in the form of a parachute attached to the tail. Normally the parachute is stowed in a special container in the fuselage and is released by the timer when it opens downstream and increases the total drag of the machine, thus steepening the gliding angle and increasing the sinking speed, but reducing the forward speed. The parachute, which can be made of tissue or silk, must be of quite large diameter to be effective and must be carefully constructed to open properly. A vent is necessary to prevent oscillation when open.

A British scheme, developed by R. Copland and tested on rubber driven models and a large glider, is interesting. This is simply a weight carried in a small compartment at the nose of the fuselage, normally sealed by a trap. The timer releases the trap door catch and allows the weight to fall out. This weight is attached to the extreme rear of the fuselage by a length of thread and thus hangs down from the tail. The effect on the flight of the models tested to date is to slow the model up until it has very little forward speed, at the same time considerably increasing the sinking speed. Thus the model descends rapidly under perfect control and on an even keel and lands on its undercarriage.

The ideal dethermaliser should increase the sinking speed of the model and decrease the forward speed, when there is the minimum risk of damage on landing. All of the latter three types described above do this. The four types described are about the best developed to date. Other experiments with wing flaps, drag flaps, split rudders, changing wing incidence, wing spoilers, etc., have proved disappointing, although some show promise.

APPENDIX I

British Record Classification

Class A.—Petrol models powered by motors having a capacity not greater than 2·5 c.c.

Class B.—Petrol models powered by motors having a capacity of more than 2·5 c.c. but not greater than 5 c.c.

Class C.—Petrol models powered by motors having a capacity of more than 5 c.c. but not greater than 10 c.c.

Models must comply with the S.M.A.E. fuselage formula, i.e, minimum area of maximum cross section of fuselage = (length) ^{2}/100.

Tailplane area must not exceed 33 per cent. of the main wing area. No restriction as to loading.

U.S.A. (N.A.A. Power Model Rules)

Class A.—Models having a wing area up to 225 sq. ins. Motor capacity not greater than ·20 cu. ins.

Class B.—Models having 226 to 450 sq. ins. wing area. Motor capacity not greater than ·30 cu. ins.

Class C.—Models having 451 sq. ins. wing area and over. Motor capacity not greater than 1·25 cu. ins.

Models must conform to N.A.A. fuselage cross-section rule and total weight must not exceed 7 lbs. A minimum wing loading of 8 ozs. per sq. ft. is called for, and a minimum weight of 80 ozs. per cu. inch piston displacement of motor.

APPENDIX II

Present Air Ministry Regulations Governing the Flying of Petrol Driven Model Aircraft (October, 1944)

(i) There is to be no flying between the hours of sunset and sunrise.

(ii) There is to be no flying in officially prohibited areas or within two miles of any Royal Air Force station.

(iii) Models are to be set to fly in closed circuits only.

(iv) Wing span not to exceed 10 ft.

(v) Maximum length of motor run to be 45 seconds.

(vi) Maximum time airborne is to be 2 minutes.

Printed in England by The Sun Engraving Co. Ltd., London and Watford.

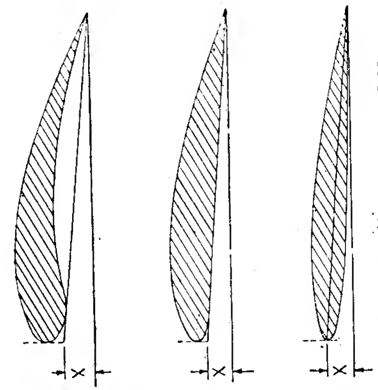
RIGGING INCIDENCE—TRANSFORMATION TABLE

TABLE I

Chord in inches	Incidence in Degrees													
	½	1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7
5	·04350	·0875	·1310	·1745	·2180	·2615	·3050	·3490	·3925	·4360	·4790	·5225	·5660	·6095
5½	·04785	·09625	·1441	·19195	·2398	·28765	·3355	·3839	·43175	·4796	·5269	·57475	·6226	·67045
6	·0522	·1050	·1572	·2094	·2616	·3138	·3660	·4188	·4710	·5232	·5748	·6270	·6792	·7314
6½	·05655	·11375	·1703	·22685	·2834	·33095	·3965	·4537	·51025	·5668	·6227	·67925	·7358	·79235
7	·0609	·1225	·1834	·2443	·3052	·3661	·4270	·4886	·5495	·6104	·6706	·7315	·7924	·8533
7½	·06525	·13125	·1965	·26175	·3270	·39225	·4575	·5235	·58875	·6540	·7185	·78375	·8490	·91425
8	·6696	·1400	·2096	·2792	·3488	·4184	·4880	·5584	·6280	·6976	·7664	·8360	·9056	·9752
8½	·07395	·14875	·2227	·29665	·3706	·44455	·5185	·5935	·66725	·7412	·8143	·88825	·9622	1·03615
9	·0783	·1575	·2358	·3141	·3924	·4701	·5490	·6282	·7065	·7848	·8622	·9405	1·0188	1·0971
9½	·08265	·16625	·2489	·33155	·4142	·49685	·5795	·6631	·74575	·8284	·9101	·99275	1·0754	1·15805
10	·0870	·1750	·2620	·3490	·4360	·5230	·6100	·6980	·7850	·8720	·9580	1·045	1·132	1·219

The table above is used when checking rigging incidences of the wing or tailplane as described on page 38. The method of checking given in the text gives the incidence as a distance between two marks on a piece of card or paper. This distance must be accurately measured with a ruler, preferably one which is graduated in 50ths or 100ths of an inch. That is, the measurement should be determined to two places of decimals. Knowing the root chord the incidence can then be verified from the Table.

For example: For a wing chord of 6 ins. set at one degree the table shows that the incidence measured should be .105 ins. The rigging check should agree with this figure.



MEASUREMENT 'X' IS GIVEN IN TABLES

Incidence is defined roughly as the inclination of the wing (or tailplane) to the datum (which is usually the centre line of the fuselage). Positive incidence is an upward inclination and negative incidence a downward inclination. In the case of an aerofoil with a concave undersurface incidence is measured from the lower tangent (i.e. a straight-edge held against the lower surface). Where the aerofoil has a flat undersurface the incidence is simply the inclination of this surface, whilst with a bi-convex section the inclination of a line through the leading and trailing edges is used.